ENCYCLOPÆDIA METROPOLITANA;

OR,

UNIVERSAL DICTIONARY OF KNOWLEDGE,

ON AN ORIGINAL PLAN:

COMPRISING THE TWOFOLD ADVANTAGE OF

A PHILOSOPHICAL AND AN ALPHABETICAL ARRANGEMENT,

WITH APPROPRIATE ENGRAVINGS.

EDITED BY

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Second Division.

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Agriculture.

FROM the great interest attached to its operations and results, Agriculture, at a very early period, began to attract the attention of Mankind. Even in the rudest state, wherever the Human Being is found to observe the institutions of social life, some care is bestowed on the improvement of the soil, and on the preservation of its produce. The wandering shepherd, whether in the wilds of Arabia or in those of the Western continent, has some favoured spot on which he cultivates the natural grasses, and exercises his skill in raising such fruits or herbs as may supply to his household a little variety in their meals, or a remedy in their sickness. The maintenance of his herbs, too, during the inclemency of the seasons, more or less incident to every climate, suggests to him the manifold advantages which may be derived from adding to the fertility of the soil; and hence the gradual transition from the pursuits of a Pastoral society to the more improved habits of the Agriculturist, who enacts laws, fixes barriers around the claims of property, and establishes the grounds of personal rights. For this reason, Ceres, the Goddess of Agriculture among the Ancients, was described as the first legislator, (*legifera*, θεσμοφόρος,) and the Poet accordingly tells us,

> *Prima Ceres unco glebam dimovit aratro,*
> *Prima dedit fruges alimentaque mitia terris,*
> *Prima dedit leges. Cereris sunt omnia munus.*

It is not surprising that the importance of husbandry to the comfort and advancement of the Human race should have led the Mythologists of the East to ascribe divine honours to those persons by whom its various processes were originally introduced. We are told that the Kings of Persia in former days relinquished, once every month, the pomp of sovereignty, and the dainties of the Royal table, and partook of the simple fare of the peasant; preserving thereby the remembrance of the primeval equality which subsisted among Mankind, and affording a sensible token of the high estimation in which Agriculture was held by their people. In modern times, a practice somewhat similar is said to prevail among the Chinese: the monarch every year, at the commencement of Spring, divests himself of all the ensigns of Imperial dignity, puts his hand to the plough, and, offering up a solemn sacrifice, prays for a favourable season and an abundant crop.

History. The Jews.

Rural Economy divides itself into two great heads. First, the cultivation of the soil for vegetable productions; and, secondly, for the rearing of live stock. The former is more strictly identified with Agriculture properly so called, while the latter comprehends the objects of the breeder, the dairy-man, the shepherd, and even the butcher. But as the improvement of land, including the various Arts by which it is rendered more fertile, applies to the one branch as well as to the other, they are very naturally considered as constituting one subject, united by relations which, resting on their first principles, extend throughout their minutest details. It is our intention, therefore, to embrace in the present Essay both these departments of rural industry; beginning with a Historical outline of the former as it was practised among those ancient nations, whose writings are best known to us.

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Of the Jews.

Although the Hebrew Tribes were in general devoted to the pursuits of Agriculture, being by their Religion precluded from commerce with the surrounding States, we are not supplied with such particulars in regard to their practice as might lead us to a just view of their system. The vine and the olive, which, on the calcareous rocks of Palestine, yielded a plentiful return to the cultivator, occupied, it is probable, more attention than the corn which grew in the valleys. This last, watered by the streams which flowed from the neighbouring hills, or cherished by the former and the latter rain, arrived at a speedy maturity under the glowing sun of a climate approaching to the tropical; and, without the exercise of much skill or trouble, filled the barn of the husbandman with an increase of thirty or even sixty fold. The plain through which the Jordan carries its stream, enjoyed in some degree the benefit conferred upon Egypt by the Nile; being partly covered by the annual inundation arising from the melting snows of the Syrian mountains. The septennial rest, too, secured for the land by the institutes of the Divine Legislator, would contribute

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Its obscurity.

in no small degree to recruit its powers, and thereby would supersede, to a certain extent, the means usually employed for reviving the strength of an exhausted soil. But it may be sufficient to observe, that the Literature of the Jews, occupied with higher objects, has conveyed to us no record of the manner in which they ploughed and sowed their fields. We find nothing beyond allusions to their rural habits and usages. The Prophet Isaiah, for example, asks, "Doth the ploughman plough all day to sow? Doth he open and break the clods of his ground? When he hath made plain the face thereof, doth he not cast abroad the fitches, and scatter the cummin, and cast in the principal wheat, and the appointed barley, and the rye in their place? For his God doth instruct him to discretion, and doth teach him. For the fitches are not threshed with a threshing instrument, neither is a cart-wheel turned about upon the cummin, but the fitches are beaten out with a staff, and the cummin with a rod. Bread-corn is bruised; because he will not ever be threshing it, nor break it with the wheel of his cart, nor bruise it with his horsemen."*

Under their Kings.

It would appear, however, that Agriculture was held in high esteem even by their Princes. The Crown-lands in the time of King David were managed by seven officers; one was over the storehouses, one over the work and tillage of the ground, one over the vineyards and wine-cellars, one over the olive and oil-stores, and sycamore plantations, one over the herds, one over the camels and asses, and one over the flocks.† King Uzziah, too, "built towers in the desert, and digged many wells; for he had much cattle both in the low country and in the plains; husbandmen also and vine-dressers in the mountains, and in Carmel, for he loved husbandry."‡ We are informed, moreover, that Elijah found Elisha in the field with twelve yoke of oxen and himself with the twelfth. It is well known that both oxen and asses were used in ploughing; but Moses forbade the Jews to yoke an ass with an ox; their step or progress being different, and their labours of course unequal.

Division of lands.

In the later period of their history, the Hebrews, like all other nations of long standing, connived at the possession of large landed estates, although one of their Prophets denounces a curse against those who join house to house, and lay field to field, that they may be placed alone in the midst of the Earth. In the earlier and more simple times, however, it should seem, that while some portion of the land was occupied exclusively by individuals, the greater part was held in common, or in a certain rotation, according to a practice not yet wholly extinct in some districts of Great Britain. This view is confirmed, not only by the regulations laid down by the Jewish Legislator as to herds and flocks, but also by the beautiful story of Ruth, who "came and gleaned in the field after the reapers, and her hap was to light on a part of the field—that is, of the common field—belonging to Boaz."

Of the Egyptians and Assyrians.

The Agriculture of the Egyptians and Assyrians seems to have taken its character from the peculiarities of the country which they respectively occupied. The annual floods which covered their land to a great extent, saved the labour of tillage, and superseded the use of those instruments which, in other parts of the World, were necessary to prepare the soil for receiving the seed. The depositions left by the water formed so rich a mould, that the exertions of the husbandman were confined to the structure of dikes, or the excavation of subsidiary canals. In Egypt the grain sown in the month of November was generally found ripe about the end of March; and during the remainder of the season, pulse followed the grain, and the fruits were succeeded by new flowers. In seconding the liberality of Nature, Man was industrious, and the duty of Agriculture was enforced by various maxims of Religion. The care of tillage, as well as of all other momentous concerns, was originally under the inspection of the Sacerdotal Families, who had of old taught the people how to drain the marshes of the Delta; the smaller mouths of the Nile long bearing the most evident marks of the patient labour which had been necessary to open and keep them clear. Aristotle assures his readers that all the inferior channels by which the river finds its way to the Mediterranean were, χειροποίητα, the work of men's hands.*

History. Assyrians, Egyptians, Greeks.

Irrigation neglected by the Persians.

The Euphrates performed nearly the same service to the plains of Mesopotamia which the Nile rendered to the valley of Egypt. The Persians, however, originally accustomed to a hilly country, viewed with contempt the magnificent works raised by the Assyrians for directing the current of the river; and the Agriculture and wealth of the Country, accordingly, very soon fell into decay. Alexander, whose attention was directed to every species of useful industry, repaired the reservoirs and canals, which he saw to be indispensable in a region where all is desert that cannot be duly supplied with moisture, and where all is exuberant fertility that can be flooded and drained at the proper seasons.† We have already suggested that the great vale of Palestine was probably cultivated in a similar manner by its ancient inhabitants; and, in confirmation of this opinion, we may quote a part of the sacred narrative which relates, that "Lot lifted up his eyes, and beheld all the plain of Jordan, that it was well watered everywhere, before the Lord destroyed Sodom and Gomorrah, even as the garden of the Lord, like the land of Egypt."‡

Restored by Alexander.

Of the Greeks.

It is not easy to determine the period at which Agriculture assumed a regular form among the Greeks. Before the arrival of Egyptian colonies the cultivation of the ground might occasionally employ the industry of scattered families; but it is manifest that this valuable Art was not considered as an object of general concern until a much later period. Cecrops is said to have induced the roving hunter and the no less migratory keeper of flocks to relinquish their unsettled mode of life, and to unite in villages under the character of husbandmen. Corn, wine, and oil rewarded their useful labours; and these productions being acquired by common exertion, were regarded, as well as the land itself, as a common property. When a warlike Tribe sallied from their woods and mountains to take possession of a more fertile territory, the soldiers fought and conquered, not for their leaders, but for themselves. The fields acquired by their united valour were considered the inheritance of all who could follow the national banners; and who, at the end of harvest, received their respective shares of the annual produce for the maintenance of their several households. It is true that the wisdom or valour of a Chief was frequently honoured by his Tribe with a valuable allotment of ground set apart for his particular use. This was cultivated, however, not by the hands of his martial

* xxviii. 24. &c. † 1 *Chron.* xxvii. 25. &c. ‡ 2 *Chron.* xxvi. 10.

* *Meteorol.* lib. i. c. 14. Plin. *Hist. Nat.* lib. xviii. c. 37.
† Arrian, lib. vii. c. 22. ‡ *Genesis*, xiii. 10.

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associates, who laboured only for the community, but by the captives taken in war, of whom a considerable number was always bestowed upon the General.

Traditional discoveries.

Tradition mentions the original production of the olive, the first culture of the vine, and even the first sowing of corn. The first use of mills for grinding is also recorded. The preparation of a lasting food from milk by converting it into cheese, and the domestication of bees for their honey and wax, were said to have been made known by Aristæus who went from the banks of the river Triton in Africa. So important was this knowledge esteemed by the rude inhabitants of ancient Greece, that in return for it they conferred upon him the honour of being called the son of Apollo, the God of Science; the herdsmen and rustic maidens among whom he had been educated, were, in like manner, raised in imagination to a rank far above that of Human nature, while he himself was at length pronounced to be immortal.*

It is remarked by Cicero, that Hesiod in his Poem on Husbandry makes no mention of manure; but Homer expressly speaks of dunging land, as well as of ploughing, sowing, reaping corn, and mowing grass. The culture of the vine, too, was well understood at the same period, and the making of wine was carried through the several processes with much attention and skill. This is evident from various circumstances mentioned by the Poet, and particularly from the age to which wines were kept. Nestor produced some at a sacrifice eleven years old. In the Gardens of Alcinous, the vine is a principal feature taken by itself, while the olive is found only in the orchard with the apple, the pear, the pomegranate, and the fig. Pasturage in all Countries has usually preceded tillage, and we find, accordingly, that in the time of Homer, flocks and herds constituted the principal fund of wealth. Cattle were even the ordinary measure of value in the exchange of commodities. The golden armour of Glaucus, for example, is described as being worth a hundred oxen; the brazen accoutrements of Diomed are estimated at nine; the tripod which was given as the first prize for wrestling at the funeral of Patroclus was valued at twelve oxen; while the female slave, the second prize, was accounted only equal to four. When again Eumæus, in the *Odyssey*, wished to convey an idea of the opulence of Ulysses, he tells neither of the extent of his lands, nor the quantity of his movables, but of his herds and flocks only. Commerce, as we might expect to find at that early period, was carried on almost entirely by barter. In the *Iliad*, for instance, there is mention made of a supply of wine being brought by sea to the Grecian camp; where, says the Poet, it was bought by some with brass, by some with iron, by some with hides, by some with cattle, and by others with slaves.†

Incidental notices by Homer.

Implements.

We need scarcely add, that at a period so remote, the implements of husbandry were extremely imperfect; the plough itself, the most useful of them all, being composed entirely of wood. The Greeks employed in the time of Hesiod the invention of shears for depriving the sheep of their wool; having formerly waited the season of its annual separation by Nature. Barley was the principal produce of their fields, and furnished the ordinary food both of men and of horses. The invention of mills was unknown, and the grain underwent several tedious operations in order to facilitate the bruising of it between two large stones with the hand.

History. The Greeks.

Dangers of Northern Greek Agriculture according to Xenophon.

Xenophon has bequeathed to posterity some remarks on the state of Agriculture in his native Country. He admits that, in most parts of Greece, soil and climate did much for the cultivator: but it is not concealed that, amid the ravages of war and sedition, the exertions of Art were hasty and unsystematical. He has, in fact, drawn a very unfavourable picture of the life of a husbandman in two of its largest and most fruitful Provinces. It occurs in the description of an entertainment given by the officers of the Cyreian army, while encamped near Cotyora, to the ministers of Corylas, Prince of Paphlagonia. Among both Greeks and Barbarians, as among the Eastern nations at this day, the meal was commonly succeeded by dances and pantomimes. After one of these movements, performed to the sound of the flute by two Thracians as targeteers, some Ænians and Magnetes, people of the Thessalian borders, stepped forward, and in the full armour of the phalanx exhibited the dance called the Carpæan. The manner of it, says Xenophon, was this: "While the pantomimic dance was proceeding to the music of the flute, one advances as a husbandman. Grounding his arms, he sows and drives his oxen, often looking round as if in fear. Another approaches as a robber. The husbandman seeing him runs to his arms, and a combat ensues. The robber prevails, binds the Agriculturist, and drives off the cattle. Then the dance is varied; the husbandman is victorious, binds the robber's hands behind him, yokes him with the oxen, and drives off altogether."*

Less perilous in Southern Greece.

In Laconia and Attica, as well as some other parts of Southern Greece, the situation of the cultivator was unquestionably less unfortunate. It was not at all times necessary for the ploughman to carry arms, while he and his cattle were sufficiently protected from at least the solitary robber. Yet, if we consider the state of the Country at large, we shall hardly wonder if the notices on Agriculture, left by the Greeks of the Republican times, are not among the most valuable of their writings.

Hesiod's remark on ploughing illustrates Scripture.

There is an expression in Hesiod,—whose Poem, on the *Works and Days*, is, perhaps, the most complete Treatise that has come down to us on the Agriculture of ancient Greece—which helps to explain a passage in the Gospel not generally nor sufficiently understood; "He that putteth his hand to the plough and looketh back, is not fit for the Kingdom of Heaven." Describing the character of a good ploughman, the Ascræan remarks, that he must not let his eye wander about, nor be absent in mind, but be careful that he may cut a straight furrow, and not sow the same twice.† The imperfect instrument called a plough in those days required incessant attention, being guided with only one hand; and it is not improbable that, in some parts of the Country, it was the practice to deposit the seed in the furrow with the other hand, while the process of ploughing was going on. In this case a vigilant eye would be still more indispensable.

Of the Romans.

If there be any deficiency in the writings of the Greeks on the subject of Agriculture, there is an ample compensation to be found in those of the Romans. In

* Justin, lib. ii. c. 6. Plato, *de Leg.* lib. vi. Pausan. lib. iii. c. 20. Diod. Sic. lib. iv. c. 83. Pindar. *Pyth.* 9.

† *Iliad*, lib. xiv. v. 296. lib. xxiii. v. 702. *Odys.* lib. xiv. v. 100. *Iliad* lib. vii. v. 467.

* *Anab.* lib. vi. *sub initio.*

† ii. 441.

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the Works of Cato, Varro, Virgil, Columella, Pliny, and Palladius, we possess all the information which might be required either to gratify curiosity or to aid the History of an important Art; and as it has been remarked, instead of schemes produced by a lively imagination, which we receive but too frequently from authors of genius unacquainted with the practice of Agriculture, we have good reason to believe that they deliver in their volumes a genuine account of the most approved usages, of which they themselves had experienced the utility. It is asserted, too, that if in the theory of their profession the Roman cultivators were inferior to the Moderns, they were greatly superior to our best improvers in attention to circumstances, in exactness of execution, and in economical management.*

Causes of Roman superiority.

In the first Ages of the Commonwealth the lands were occupied and cultivated by the proprietors themselves, men accustomed to the activity and precision of military life; and as this state of things continued four or five centuries, it was probably the chief cause of the Agricultural eminence of the Romans. An observation made by Pliny confirms this supposition; for he assures us that his Countrymen, in early times, ploughed their fields with the same diligence that they pitched their camps, and sowed their corn with the same care that they arranged their armies in the day of battle. Afterwards, when Rome extended her conquests, and acquired large territories, individuals became owners of wide domains, the culture of which fell into inferior hands.

Mode of farming lands.

Such estates were either committed to the management of responsible servants, who had under them a great number of slaves, or let out to farmers, who occupied a portion of the soil on certain conditions and for a limited period. Generally speaking, the stock on the farm belonged to the landlord, and the cultivator received only a specific portion of the produce in return for his labour and superintendence. In reference to this position, the latter was called *politor* or *polintor*, the dresser of the soil; while, from being in a kind of copartnership with his superior, and receiving a share of the produce, he was sometimes denominated *partuarius*. Cato has recorded that, in the best land, the *politor* obtained the ninth basket; in the second kind of land, he got the eighth; in the third description he received the seventh; and in a still inferior, he was remunerated by being allowed to retain the fifth.

Columella's instructions to landlords.

The *Coloni*, or farmers properly so called, seem to have paid rents for their ground in a manner nearly similar to that which is observed among ourselves. The directions given by Columella to a landlord concerning the mode of treating that class of men are curious as well as important, and not altogether inapplicable at the present day. He ought, says he, to conduct himself towards his tenants with gentleness, should show himself not difficult to please, and be more solicitous to exact culture than rent, because this is less severe, and, upon the whole, more advantageous. For when a field is carefully cultivated, it for the most part brings profit, never loss, except when assaulted by a storm or pillagers. Neither should the landlord be very tenacious of his right in every thing to which the farmer is bound, particularly as to days of payment, and demanding the wood and other small things which he is obliged to furnish, the care of which is greater trouble than expense to the rustics. Nor is every penalty in our power to be exacted,

* Dickson, *Husbandry of the Ancients*, vol. i. p. 16.

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for our ancestors were of opinion that the rigour of the law is the greatest oppression. On the other hand the landlord ought not to be entirely negligent in this matter; because it is certainly true what Alpheus the usurer was wont to say, that "good debts become bad ones by not being called for."*

Agricultural servants.

The servants employed in Roman Agriculture were either freemen or slaves. When the proprietor lived on the farm and directed its culture, these were, of course, under his own management; in other cases there was an overseer to whom all the labourers were subordinate. This agent was generally a person who had received some education, although Columella thinks that he might transact business very well without the use of letters; and Cornelius Celsus adds, that the illiterate bailiff is to be preferred, because he will bring money to his master oftener than his book, since being ignorant of figures, he will be the less capable to contrive accounts and the more afraid to trust others.

Price of labour.

As far as we can compare prices in ancient and modern times, it does not appear that Agricultural labour was cheap among the Romans, even when they employed the hands of slaves. In the days of Cato, the price of a slave was about £50; in those of Columella, it had risen to £60; being the value of eight acres of good land. An expert vine-dresser cost £66. 13*s*. 4*d*., and a ploughman about the same sum. The interest of money at that period was 6 per cent.; therefore in estimating the expense of farm-labour, the work of a slave, being a perishable commodity, ought to be rated at not less than 12 per cent. on his purchase money. Hence one who cost £60 must be charged at £7. 4*s*. yearly, besides his clothing and maintenance.†

Ploughing.

Of all Agricultural operations, the Romans attached the greatest importance to ploughing. What, says Cato, is the best culture of land? Good ploughing. What is the next best? Ploughing. What is the third? The application of manure. In the strong loamy soils of Italy the maxim of this sage Agriculturist could not be applied too extensively, because the richness of such land required to be excited into energy rather than to have its powers increased. In most cases a crop and a year's fallow succeeded each other; although when manure could be obtained, two crops or more were taken in succession; and in certain fertile districts described by Pliny as favourable for barley, a crop was raised every year. In fallowing, the lands were first ploughed after the crop was removed, generally in August; they were again cross-ploughed in Spring, and at least a third time before sowing. In other cases, however, there were no limits to this operation; the object being, as Theophrastus observes, "to let the earth feel the cold of Winter and the heat of Summer; to invert the soil and render it free, light, and clear of weeds, so that it might afford a full supply of nourishment to the plants."‡

Manuring.

The Roman authors lay great stress on the use of proper manure. Pliny reminds his readers that in Homer an old King is represented as spreading dung on his fields with his own hands. Augeas, a personage too of Royal station, is said to have been the first among the Greeks who discovered this method of aiding the

* Columel. lib. i. c. 7.

† *Ibid.* lib. i. c. 8.

‡ Theoph. *de caus. Plant.* lib. iii. c. 25. Cato, c. 61. *Quid est agrum bene colere? bene arare. Quid secundum? arare. Quid tertium? stercorare.* See also Pliny, book xviii c. 19.

Agriculture. resources of land. In Italy, where Hercules is reported to have divulged the secret, a lasting fame was conferred by his subjects upon King Sterculius for communicating the invention to the practical husbandman. On this head the ancient farmers on the Tiber and the Po had the merit of setting an example to future Ages, which cannot be too closely followed. They were so sensible of the advantage arising from manuring their grounds, that they were most assiduous in collecting every material which seemed proper for the purpose. Besides the usual resources supplied by the stable and fold, they gathered ashes, shrubs, stubble, burned the branches of trees, and even heaped together different kinds of earth. "You may make manure," says Cato, "of lupines, bean-stalks, chaff, holm, and oak-leaves. From the corn-fields pull out dwarf alder, hemlock, and all the tall grass and reeds in the willow plantations, and lay them below the sheep and cows." "I am not ignorant," says Columella, "that there are some farms in the country on which neither the dung of cattle nor of birds is to be procured; and yet, even in such places, he is a slothful cultivator who can find no manure. He may collect any kind of leaves, the cuttings of briers, and the rakings of highways, and mix them with the cleanings of the court-yard."*

Mixture of soils. But the Ancients were not only very diligent in the use of every animal and vegetable substance which might minister to the improvement of their lands, they also, as we are informed by Theophrastus, were wont to mix together earths of different qualities, light with heavy, fat with lean, and, in short, all those which displayed any contrariety in their nature. This mixture, he adds, not only supplies what is wanting in point of depth, but also renders the soil with which another is mingled much more powerful; so that what is worn out, being mixed with any fertile kind of earth, begins again to carry crops, as if renewed; and what is naturally barren, such as clay, is rendered fruitful by the addition of ingredients possessing an opposite quality. In fact, this mixture, when judiciously made, is considered a complete substitute for manure. The people of Megara, besides adopting the process now described, were wont to trench their fields every fifth or sixth year; and digging as deep as the rain is understood to penetrate, they brought the bottom of their soil to the top; it being a maxim with them that the particles of earth proper for the nourishment of plants, are always carried downwards as far as the surface water descends.†

Marl. Marl was known to the earlier authors of Rome, but was not used in Italy. It is mentioned by Pliny as occurring in Britain and Gaul, and is described by him as being like the kernels in animal bodies which are enervated by fatness. It was employed, he subjoins, as a manure by the Greeks, "for what is there which they have not tried?" Varro relates that, when he marched an army to the Rhine in Transalpine Gaul, he passed through Countries where he saw the fields manured with a white fossil clay, which must have been either marl or chalk.

Sowing. Sowing was performed with the hand from a basket, as in modern times; the hand, as Pliny remarks, moving with the step, and always with the right foot. The corn and leguminous seeds were covered with the plough, and sometimes so as to rise in drills; the smaller seeds were earthed with the hoe and rake.

History. The Romans.

Reaping. Varro mentions three modes of conducting the operation of reaping, which, in order to avoid the hazard attending boisterous weather, the best authors recommended to be done before the crops were fully ripened. The first method was to cut close to the ground with hooks; the second was to cut off the ears with a curved stick having a saw attached; and the third was to cut the stalks in the middle, leaving the lower part, or stubble, to be gathered afterwards. To these modes Pliny adds that of pulling up by the roots; and remarks generally, that where they cover their houses with straw, they cut high to preserve this of as great a length as possible, but that where fodder is scarce they cut low with the view of securing an addition to their forage.

By Machinery. A reaping-machine, used in the plains of Gaul, is described by Palladius in the following terms. The Gauls, says he, "use this quick way of reaping, and without reapers cut large fields with one ox in a single day. For this purpose a machine is made supported upon two wheels; the surface has boards erected at the side, which sloping outwards, make a wider space above. The board on the fore part is lower than the others; upon it there are a great many small teeth, set in a row, answering to the height of the corn, and turned upwards at the ends. At the back part of the machine two short shafts are fixed, like the poles of a litter; to these an ox is yoked with his head to the machine, and the yoke and traces likewise turned the contrary way. When this piece of mechanism is pushed through the standing corn, all the ears are enclosed by the teeth, and heaped up in the hollow part of it, being cut off from the straw which is left behind, the driver setting it higher or lower as he finds it necessary; and thus by a few goings and returnings, the whole field is reaped. The machine does very well in plain smooth lands, and in all places where the straw is not considered of any value." A conjectural delineation of this instrument is given by Lasteyrie, in his Work entitled *Collection des Machines.* (See fig. 1.)

Carrying. The Romans, says Mr. Loudon, did not bind their corn into sheaves as is customary in Northern climates. When cut it was in general carried directly to the *area* to be thrashed, or if the ears only were cropped, they were sent in baskets to the barn. Among the Jews, Egyptians, and Greeks, the corn was bound in sheaves; or at least some kinds were so treated, as we learn from the story of Ruth, who gleaned "among the sheaves;" from Joseph's dream in which his "sheaf arose;" and from the harvest represented by Homer on one of the compartments of Achilles's shield.*

Threshing. Threshing was performed in the *area* or threshing-floor, which was a circular piece of ground, fifty or sixty feet in diameter, with a smooth, hard surface. The floor, indeed, was generally made of wrought clay mixed with the lees of oil, which increased its tenacity; sometimes it was even paved. It was usually selected in the neighbourhood of the *nubilarium* or barn, in order that, when a sudden shower happened during the process of threshing, the ears might be removed thither out of the reach of damage. The corn being spread over this surface, a foot or two in thickness, was beaten out either by the hoofs of cattle, or by dragging over it a machine composed of wood and iron, and surmounted by a consider-

* Cato, c. 37. Plin. *Hist. Nat.* lib. xvii. c. 9. Colum. lib. ii. c. 15.

† Colum. lib. ii. c. 16. Theoph. lib. iii. c. 25.

* *Encyclopædia of Agriculture*, p. 26.

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able weight. Occasionally rods or flails were used for the same purpose, while the Indian corn, *far*, or maize, was picked with the hand, or pressed through a small mill.

Winnowing.

The produce of the threshing-floor was winnowed or purified from the husks and chaff by being thrown from one part of the barn to another across a current of wind. The instrument used for this end was a kind of shovel called *ventilabrum;* and to supply the absence of wind it was customary to substitute an implement called *vannus*, the origin, perhaps, of the modern and much more complex machine denominated fanners.

Ignorance of Theory.

It is remarkable that, in regard to the practical knowledge of Agriculture, the Romans were very little inferior to the most intelligent among husbandmen in our own days. They were indeed extremely deficient in point of Science, being unable to give a reason for their best established usages which did not terminate in simple experience or accident. They knew nothing of Chemistry or Physiology, were unacquainted with the analysis of soils or manures, and were especially ignorant of those principles in Mechanics which determine the strength of materials, and the application of force. Again, in accounting for many of the most ordinary phenomena of Nature, they had recourse to supernatural and imaginary causes.

Superstitions.

In the rude periods of Society, Good and Evil Spirits are supposed to take a concern in every thing; and hence the absurd superstitions of the Egyptians, and the equally whimsical ceremonies of the Greeks, to procure their favour or avert their malign influence. Hesiod, accordingly, considered it of not more importance to describe what works were to be done, than to point out the lucky days for their performance. Homer, Aristotle, Theophrastus, and all the Greek authors, are more or less tinctured with this belief, so prevalent in the darker Ages of remote antiquity. Nor were the Romans in this respect less enthralled than the ingenious People from whom they borrowed the most valuable part of their knowledge. The empire of superstition extended over all their undertakings, and none more completely than the important pursuits of Agriculture. In some cases Imagination seized the reins which should never be taken out of the hands of Reason and Experience; and hence both Virgil and Pliny venture upon statements in regard to heterogeneous grafting, the spontaneous generation and transmutation of plants, the influence of lunar days, and the impregnation of animals by certain winds, which every Physiologist knows to be altogether inconsistent with the laws of Nature.

Progress,

It is a question of curiosity rather than of Scientific importance, to determine how much Agriculture owed to the Romans, and to what extent they improved upon the usages of the Greeks and Egyptians. As the writers of Italy refer in most cases to authors who flourished at an earlier period among their neighbours beyond the Adriatic, it is probable that the leading principles of the Art were borrowed from Greece. But there can be no doubt that the progress of the Roman arms in Helvetia, Germany, and Britain extended the knowledge of tillage among barbarous Tribes by whom it was formerly unknown or neglected. The conquerors imposed a tribute of corn on the vanquished Provinces, which compelled the natives to cultivate the soil. Large fleets sailed from the shores of Britain laden with grain for the Imperial stores in various parts of their extensive dominions. Egypt, too, with Sicily and Africa, contributed immensely to feed the armies and luxurious citizens of the proud Republic, until at length, by a just retribution, she found herself at the mercy of the very Countries which she had subdued.

History. The Romans.

Agriculture which flourished abroad decayed gradually at home. The great men in Rome, trusting to their revenue from the Provinces, neglected the improvement of their estates in Italy; and while their lands became less productive, they insisted upon higher rents. The farmer, sinking under broken spirits and a diminishing capital, imitated his landlord in idleness and rapacity. The Civil wars which ensued, the tyranny of the Emperors, and at length the removal of the seat of Government to Constantinople, paved the way for the Northern invaders, and consequently for the downfal of Agriculture, and of every useful or elegant Art.

and decline of Roman Agriculture.

Implements.

In regard to implements for the uses of husbandry, the Romans possessed several, of which neither the form nor the purpose is now distinctly known. We find mentioned in their Agricultural authors the *aratrum*, the *irpex*, or *urpex*, the *crates*, the *rustrum*, the *bidens*, the *securis*, the *dolabra*, the *ligo*, the *pala*, the *sarculum*, the *marra*. By the first, as every one knows, is meant the plough, of which it appears there were varieties among the cultivators of ancient Italy. The other instruments, in their order, correspond to a weeder or breaker, a harrow, a rake, a toothed hoe, an axe or pruning-hook, a mattock, a spade, a small shovel, a hand-hoe, a scraper or Dutch hoe. In some cases these are only approximations; for we find no small difficulty in reconciling the descriptions of the several authors who have written on the rural economy of the Ancients, as well as in comparing the instruments they delineate to the more artificial tools of modern times.*

The plough.

As the plough is the most important of all Agricultural machines, we may be indulged in a few details respecting its form, more especially as Virgil, the Prince of Roman Poets, has not disdained to supply us with some particulars in regard to its construction.

Continuo in silvis magnâ vi flexa domatur
In burim, et curvi formam accipit ulmus aratri.
Huic a stirpe, pedes, temo protentus, in octo;
Binæ aures, duplici aptantur dentalia dorso.
Cæditur et tilia ante jugo levis, altaque fagus,
Stivaque quæ currus a tergo torqueat imos;
Et, suspensa focis explorat robora fumus.

Geor. i. v. 169.

Young elms with easy force in copses bow,
Fit for the figure of the crooked plough.
Of eight feet long a fastened beam prepare:
On either side the head produce an ear,
And sink a socket for the shining share.
Of beech the plough-tail and the bending yoke,
Of softer linden hardened in the smoke.

Dryden.

It is asserted in a Work entitled the *Husbandry of the Ancients*, that the Romans had all the different kinds of ploughs that we have at present in Europe, though perhaps not so exactly constructed. "They had ploughs without mould-boards, and ploughs with mould-boards; they had ploughs without coulters, and ploughs with

* These, says the author of the *Georgics*, are the rural arms, without which crops can neither be sown nor reaped.

Queis sine, nec potuere seri, nec surgere, messes:
Vomis, et inflexi primum grave robur aratri,
Tardaque Eleusinæ Matris volventia plaustra,
Tribulaque, traheæque, et iniquo pondere rastri,
Virgæ præterea Celei viliaque suppellex,
Arbuteæ crates, et mystica vannus Iacchi. lib. i. 164.

Agriculture. coulters; they had ploughs without wheels, and ploughs with wheels; they had broad pointed shares, and narrow-pointed shares; they even had what I have not yet met with amongst the Moderns, shares not only with sharp sides and points, but also with high raised cutting tops. Were we well acquainted with the construction of all these, perhaps it would be found that the improvements made by the Moderns in this article, are not so great as many persons are apt to imagine." (See fig. 2, 3, 4.)

Day observations. We have already alluded to the superstitions of the Ancients in respect to fortunate and unfortunate, and the extent to which those feelings were admitted in the processes of Agriculture. This is one instance among many wherein we discover a striking contrast between the practical good sense of a great People, and their speculative absurdity in matters of belief. Virgil, for example, in the very middle of his precepts for sowing, planting, manuring, weeding, and reaping, inserts the following admonition for the use of the Italian peasants.

Ipsa dies alios alio dedit ordine Luna
Felices operum: quintam fuge; pallidus Orcus,
Eumenidesque satæ: tum partu Terra nefando
Cœumque Iapetumque creat, sævumque Typhoëa,
Et conjuratos cœlum rescindere fratres.
* * * *
Septima post decimam felix, et ponere vitem,
Et prensos domitare boves, et licia telæ
Addere: nona fugæ melior, contraria furtis.
Geor. i. v. 276.

The lucky days in each revolving moon
For labour choose; the fifth be sure to shun:
That gave the Furies and pale Pluto birth,
And arm'd against the skies the Sons of Earth.
* * * *
The seventh is next the tenth the best to join
Young oxen to the yoke, and plant the vine.
The ninth is good for travel, bad for theft.
Dryden.

Omens of weather. Amid the indications of the weather, too, as depending upon the aspect of the heavenly bodies, the same delightful author mingles his political regrets and superstitions. The beauty of the verse will excuse us in the eye of every reader of taste for this concluding extract from the Agricultural Poem of Virgil.

Sol tibi signa dabit: Solem quis dicere falsum
Audeat? Ille etiam cæcos instare tumultus
Sæpe monet, fraudemque et operta tumescere bella,
Ille etiam exstincto miseratus Cæsare Romam;
Quum caput obscurâ nitidum ferrugine texit,
Impiaque æternam timuerunt sæcula noctem.
lib. i. v. 463.

The sun reveals the secrets of the sky;
And who dares give the source of light the lie?
The change of empires often he declares,
Fierce tumults, hidden treasons, open wars.
He first the fate of Cæsar did foretell,
And pitied Rome when Rome in Cæsar fell;
In iron clouds concealed the public light,
And impious mortals feared eternal night.
Dryden.

The decline of the Roman power was accompanied with the neglect of Agriculture in almost all the Countries which had submitted to the arms of the Commonwealth. Little

Italy. is known of the condition of this Art in Italy during the long period of twelve hundred years, as it was not till the beginning of the XIVth century that any Work appeared on that important branch of industry. About the era now specified, a Treatise entitled *Ruralium Commodorum* was written by Crescentio, a Senator of Bologna, and afterwards published in 1471. He was soon followed by several of his Countrymen, among whom Tatti, Stephano, Augustino Gallo, Sansovino, Lauro, and Torelli, deserve to be mentioned with applause. From some records, however, which have escaped the ravages of time, it appears that irrigation was practised nearly two centuries before the earliest of the dates now mentioned. The Monks of Chiaravalle had set an example in this species of improvement, and had become so celebrated in quality of hydraulic engineers as to be employed by the Emperor Frederic I. The volume of Crescentio is, in great part, a compilation from the older Roman authors, such as Cato, Varro, and Pliny; but being illustrated with figures, is valuable because it enables us to form some notion of the implements then in use. The plough is drawn by only one ox; but other kinds, which must have been drawn by two, and even by four, are described at some length. The Political troubles which so long agitated the fine Provinces Southward of the Alps, prevented them from profiting by the revival of the Arts in other parts of Europe; and hence, at the present day, although Italy can boast of a rich soil and a favourable climate, her inhabitants have no where entitled themselves to the reputation of being good farmers.*

History. Italy. France.

France. France, too, overrun by the Northern Barbarians, or by the Tribes of native Germans hardly more civilized, was long doomed to witness the decline of that pursuit upon the success of which the prosperity of all others is more or less suspended. In the XIIth century, the care bestowed by some leading Churchmen upon the produce of the soil was rewarded by a considerable melioration in the state of the peasantry, as well as in the value of lands. Four hundred years later, the first Agricultural Work produced in France made its appearance, under the title of *Les Moyens de devenir riche*, composed by Bernard de Pallisy, a potter, who is said to have written on various other subjects. Under the auspicious reign of Henry IV. great exertions were made for the improvement of the Country in general, amidst which the interests of rural economy were not forgotten. Sully asserts, in his *Memoirs*, that, in his time, France abounded with corn, grain, pulse, wine, cider, flax, hemp, salt, wood, oil, drugs for dyeing, cattle great and small, and every thing else, whether necessary or convenient for life, both for home consumption and exportation.

Great changes for the better were made in France during the last century. The celebrated Economists created a taste for the Art, and Agricultural Societies were every where established under the sanction of the Government. Those of Paris, Lyons, Amiens, and Bourdeaux distinguished themselves by the publication of some valuable *Memoirs*. The name of Buffon, too, gave reputation to this study, and various other writers contributed to make it popular. Chaptal informs us that essential improvements have been introduced since the Revolution. Crops of every kind, says he, cover the soil; numerous and robust animals are employed in labouring it, and they also enrich it by their manure. The country population are lodged in commodious houses, decently clothed, and abundantly nourished with wholesome food. We are not however to suppose, he observes, that the Agriculture of France has arrived at perfection; much still remains to be done; new plans of improvement should be more generally introduced; and a

* Loudon, p. 34. Harte, *Essays on Husbandry*.

Agriculture.

greater quantity of live stock is wanted for every Province, except two or three, which abound in natural meadows Few domains have more than half the requisite number of labouring cattle; the necessary consequence of which is a deficiency of labour, of manure, and of crop. The only mode of remedying these evils is to multiply the artificial pastures, and increase the cultivation of plants destined for forage. The rich inhabitants of France have already adopted these principles; but they have not not yet found their way among the lowest class of cultivators. According to M. Dupin, four-fifths of the peasantry of France are proprietors of land, which they cultivate themselves; and although Knowledge is rapidly advancing, they are still very ignorant. It is readily admitted, too, that France is still miserably deficient in the better kind of Agricultural instruments.

Germany.

As Germany had not shared so extensively as some other European Countries in the civilization diffused by the Romans, the reaction occasioned by the desolating wars of the IVth and Vth centuries was less deeply felt in the Provinces beyond the Rhine. Accordingly, it is not till the beginning of the XVIth century that we can discover any symptom of Agricultural advancement among the numerous Nations which extend from the borders of France to the shores of the Baltic. The earliest Work on Husbandry, by a German author, is the Treatise *De Re Rusticâ*, by Conradus Heresbachius, published about the year 1576. It is composed in the form of Dialogue, and contains an outline of the opinions and precepts delivered by the Ancients, from Hesiod down to Pliny; being, in fact, an Essay compiled from the literary materials of former Ages, rather than a Treatise on the Art as it appeared before his eyes, or which was meant to improve either its theory or practice.

Britain.

In relation to Britain, although it is certain that Agriculture was not wholly unknown before the Roman invasion, it is difficult to say when it was first introduced, or how far it had then advanced. Both the Greeks and Phœnicians visited this Island long before the Legions landed on its shores with a view to conquest; but as their visits were only transient, and for the sake of trade, it is uncertain whether they took the trouble to instruct the natives how to cultivate the soil. It is more probable that the knowledge of this important Art was brought hither by some of those Colonies which are known to have passed over from the coast of Gaul. These emigrants having been employed in Agriculture in their own Country, pursued the same employment in their new settlements. This was the opinion of Cæsar. "The sea-coasts," he observed, "are inhabited by Colonies from Belgium, which, having established themselves in Britain, began to cultivate the land."*

Introduction of Agriculture.

Agriculture, we may therefore presume, was little known in this island till about a hundred and fifty years before the beginning of the Christian Era, when great multitudes of Celtic Gauls, being expelled from their native seats between the Rhine and the Seine by the German *Belgæ*, took shelter in the South of England, where they formed several small States. These communities received reinforcements from time to time from the same coasts, whose inhabitants were then called *Belgæ*, and practised husbandry; a way of life which they were encouraged to pursue in Britain by the fertility of the soil, which produced all kinds of grain in great plenty and perfection. If we could depend on the testimony of Geoffry of Monmouth, we should be led to think that Agriculture had been greatly prized in this Country several Ages before the period abovementioned, for he acquaints us that, by one of the laws of Dunwallo Molmutius—who is said to have reigned over all Britain about five centuries before the birth of Christ—it was declared that the ploughs of the husbandmen, as well as the Temples of the Gods, should be held as sanctuaries to such criminals as fled to them for protection.† But this is thought to be only one of the many fables related by that author, the law to which he alludes being of a much later date: and upon the whole the truth seems to be that, though Agriculture might be practised a little by a few of the more ancient Britons, yet it was chiefly introduced by the Belgic Gauls, about a century before the first Roman invasion, and almost wholly confined to them till after that event.

History. Germany. Britain.

Early manures.

Very few of the peculiar practices of the most ancient British husbandmen are preserved in History. It appears that they were not unacquainted with the use of manures, for renewing and increasing the fertility of their grounds; and that, besides those which were common to other Countries, they had one peculiar to themselves and the Gauls. This was marl, which we have already noticed in the quotation from Pliny. The same writer, after describing different kinds of that substance, remarks, "of those which are esteemed the richest, the white ones are most valued, and of these there are several species. First, one which hath a most sharp and piquant taste; another kind is the white chalky marl, much used by silversmiths: for this they are sometimes obliged to sink shafts one hundred feet deep, when they find the vein spreading broader, as in other mines. It is this kind of marl which is most used in Britain. Its effects are found to continue eighty years; and no man was ever known to have manured the same field with this marl twice in his lifetime."† It is highly probable that lime was also employed for the same purpose by our remote ancestors, because we know with certainty that it was so used in Gaul, from whence the knowledge of it might easily be conveyed.

Marl.

Lime.

The instruments and method of ploughing, sowing, and reaping in this Country were no doubt the same as among the Gauls from whom they were derived; and these probably were not very different from such as were used in Italy during the times of which the practice is so fully described by the Roman writers on Agriculture. Diodorus Siculus has recorded some remarkable particulars relating to the manner in which the most ancient British husbandmen preserved their grain, after it was reaped, and prepared it for use. They cut the ears from the stubble, says he, and lay them up for preservation in subterraneous caves or granaries. From thence they relate that, in very remote times, they used to take a certain quantity of these ears every day, and having dried and bruised the grains, made a kind of food of them for immediate eating.‡ Though these methods were very slovenly and imperfect, they were not peculiar to the old Britons, but were practised by other nations, and some vestiges of them

Diodorus Siculus.

* *De Bell. Gall.* lib. v. c. 12.

* Gaulfrid. *Monum.* lib. ii. c. 12.

† *Hist. Nat.* lib. xvii. c. 8.

‡ Lib. v.

Agriculture.

were remaining not long ago in the Western Isles of Scotland.*

Encouragement given by the Romans to British Agriculture.

As soon as the Romans had attained a firm establishment in Britain, Agriculture began to be improved and extended; it being an Art in which that renowned people greatly delighted, and which they encouraged in all the Provinces of their Empire. When, according to Cato, his Countrymen designed to bestow the highest praise on a good man, they used to say, "he understands Agriculture well, and is an excellent husbandman; for this was esteemed among them the greatest and most honourable character." As soon, therefore, as the soldiers of the Republic had subdued some of the British States, they endeavoured by various means to induce their new subjects to cultivate their lands, in order to render their conquest more valuable. In fact, the tribute of a certain quantity of corn which they imposed on their vassals, compelled the mass of the people to apply to Agriculture. The veteran colonists too, who were not less expert at guiding the plough than wielding the sword, set before the natives an example both of the most improved method, and the manifold advantages of this branch of industry. In short, the Romans by their power and policy, and more especially by their superior knowledge, so completely reconciled the Britons to the cultivation of their lands, that in a little time this Island became one of the most plentiful Provinces of the Empire, and not only produced a sufficient quantity of corn for the support of its own inhabitants and the Roman troops, but afforded every year a very great surplus for exportation. This became an object of so great importance that a fleet of ships was provided for the particular service of carrying corn from Albion to granaries on the opposite coasts, whence it was conveyed into Germany and other Countries for the use of the armies. We are informed by Ammianus Marcellinus, that the Emperor Julian having collected prodigious quantities of timber from the banks of the Rhine, built a fleet of a hundred ships, larger than the common barks, which he sent to Britain, in order to bring corn thence. When it arrived, he sent it up the Rhine in boats, and furnished the inhabitants of those towns and Countries which had been plundered by the enemy with a sufficient quantity to support them during the Winter, to sow their lands in the Spring, and to maintain them till next harvest.†

Obscurity of its progress.

We have sufficient evidence that the knowledge of husbandry, and indeed of all the other Arts, entered Britain at the South-Eastern corner, and travelled by slow and gradual steps towards the North-West; but it is difficult to trace the progress of these Arts, or to discover how far they had advanced at any given period. With regard to Agriculture we are assured by a contemporary author, that in the beginning of the IIId Century, it had not proceeded further than the wall of Hadrian. In the year 207, when the Emperor Severus invaded Caledonia, we are told that the natives "inhabited uncultivated mountains, or desert marshy plains; that they had neither walls, towns, nor cultivated lands, but that they lived on the flesh and milk of their flocks and herds, or what they got by plunder, or catched in hunting, or on the fruits of trees." The Mæatæ and Caledonians having been obliged by Severus to yield up a part of their Country to the Romans, that industrious people, in the course of the IIId Century, built several towns and stations, constructed highways, cut down woods, drained marshes, and introduced Agriculture into the country between the walls, many parts of which are very fertile and fit for tillage. Although they never formed any large establishment Northward of the wall which joined the firths of Forth and Clyde, yet many of them, as well as of the Provincial Britons, retired into Caledonia at different times, particularly about the end of the IIId Century, during the heat of the Diocletian Persecution. It is therefore highly probable that these refugees instructed the people among whom they settled not only in their Religion, but also in their Arts, and especially in that of Agriculture. The name which was given to the Caledonians of the Eastern coast by those of the Western, was *Cruitnich*, which signifies corn-eaters, a convincing proof that the latter were husbandmen. From other facts it is clear that in the beginning of the Vth Century the Scots of the mountains lived partly upon meal; a kind of food to which they had been absolute strangers about two hundred years before, when they were first startled by the appearance of the Roman Eagles under Severus.

Its decline after the withdrawal of the Romans.

When the Roman power declined in Britain, Agriculture with the other Arts of civilized life fell into comparative neglect. This was not so much owing, however, to want of skill in the native husbandmen, as to the frequent incursions of the Saxons, who had already begun to enrich themselves with the plunder of the English; and who, together with the Scots and Picts from the North, not only destroyed the fruits of their labours, but also disturbed them in the exercise of their industry. We need not be surprised, therefore, that the posterity of the ancient Britons became rather unskilful Agriculturists, and that they thenceforth applied themselves more to pasturage, than to the culture of an unprotected soil. It is clear, notwithstanding, that, even in its most depressed condition, Agriculture was regarded by them as worthy of attention in a legal point of view, and hence was made the object of several characteristic enactments. They prohibited, for example, the use of horses, mares, or cows in the plough, and restricted the farmer to certain yokes of oxen. Their implements, it is true, were very slight and inartificial; for it was regulated by statute that no man should undertake to guide a plough who could not make one; and that the driver should be able to make of twisted willows the harness with which it was drawn. But simple as these ploughs were, it was usual for six or eight persons to form themselves into a Society for fitting out one of them and providing it with oxen. This is a sufficient proof both of the poverty of the class of men who occupied land, and of the very imperfect state of Agriculture among the Britons at the period in question. If any person laid dung upon a field, he was allowed by law and the consent of the proprietor, to use it for one year; and if the dung was conveyed thither on a cart and in a certain quantity, he was allowed the use of the field for three years. If any man folded his cattle for a whole year upon a piece of ground belonging to another, with his consent, he was allowed to cultivate that ground for his own benefit during the space of four years. All these laws were evidently meant for the encouragement of Agriculture, by increasing the quantity and improving the quality of the arable lands.*

Despised at first by the Anglo-Saxons.

As the Anglo-Saxons derived their origin and manners from the ancient Germans, who depended for sub-

* See Martin, p. 204.

† Lib. xviii. c. 2.

* *Leges Wallicæ*, p. 298.

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sistence chiefly on their flocks and herds, it may be inferred that they were not much addicted to Agriculture. On the contrary, these haughty warriors esteemed the cultivation of the land too ignoble an employment for themselves, and therefore committed it wholly to their women and slaves. The Chiefs were even at pains to contrive laws to prevent their followers from contracting a taste for Agriculture, lest it should render them less fond of arms and of warlike expeditions. Hence we may conclude that the Anglo-Saxons at the time of their arrival in Britain, were much better warriors than husbandmen; and we find, accordingly, that for a considerable period after they completed their settlement, their attention was almost exclusively confined to deeds of arms. It was not until they had no longer any enemies to plunder, that they found it necessary to devote some portion of their cares to the improvement of the land, in order to raise those provisions which it was no longer possible to procure by the edge of their swords.

Division of Lands.

In the division of the Country, those of the leaders who obtained the largest shares are said to have subdivided their estates into two parts, which were called the *inlands* and the *outlands*. The inlands were those which lay contiguous to the mansion of their owner, which he kept in his own immediate possession, and cultivated by his slaves for the purpose of supplying provisions to his family. The outlands were such as lay at a greater distance from the dwelling of the lord, and were let to the ceorls or farmers at a moderate rent, which was generally paid in kind. The owners of land were not permitted to exact as high a rent from their tenants as they might have obtained by throwing open their lands to competition; the several payments being fixed by law, according to the number of hides or plough-lands of which a farm consisted. The reason of this seems to have been that the first ceorls among the Anglo-Saxons were freemen and soldiers, who had contributed by their arms to the conquest of the Country, and who were therefore entitled to the indulgence just mentioned. By the Laws of Ina, King of the West Saxons, who flourished at the beginning of the VIIIth Century, a farm consisting of ten hides or plough-lands was to pay the following rent, namely, ten casks of honey; three hundred loaves of bread; twelve casks of strong ale; thirty casks of small ale; two oxen; ten wethers; ten geese; twenty hens; ten cheeses; one cask of butter; five salmon; twenty loads of forage; and one hundred eels.* In some places these rents were paid in wheat, rye, oats, malt, flour, hogs, sheep, according to the nature of the farm or the custom of the country.†

Rents in produce,

in money

There is, however, sufficient evidence that money-rents were not altogether unknown in England, at this period, although the other system prevailed much more extensively. For instance, the greater part of the Crown-lands was farmed in that manner by ceorls, who paid a certain quantity of provisions for the support of the King's household, according to the nature of the grounds which they occupied. "We have been informed," says the author of the *Liber Niger Scaccarii*, "that in ancient times our Kings received neither gold nor silver from their tenants, but only daily provision for the use of their household; the officers who were appointed to manage the King's lands knew very well what quantities and what kinds of provisions every tenant was obliged to pay. This custom continued even after the Conquest, during the whole reign of William I.; and I myself have conversed with several old people who had seen the Royal tenants paying their rents in several kinds of provisions at the King's Court."*

Prices evince great deterioration of Agriculture.

In the ancient *History of the Church of Ely*, published by Dr. Gale, the curious reader will find an account of several purchases of land which were made by Æthelwold, the founder of that church, and by other pious benefactors, in the reign of Edgar, surnamed the Peaceable. By comparing these documents it plainly appears that the ordinary price of an acre of the best land in that part of England, in the Xth Century, was sixteen Saxon pennies, or about four shillings of our money; a very trifling sum indeed, not only in comparison with the prices of land in our times, but even in comparison with the prices of other commodities at the same period. The insecurity of territorial possessions in that rude Age, not only depressed its value; it also necessarily led to the neglect of all the proper means for increasing its produce. The frequent famines which afflicted England, and carried off multitudes of the inhabitants in those days, afford a further and more melancholy proof of the wretched state of cultivation. In particular, there was so great a scarcity of grain in the year 1043, that a quarter of wheat sold for sixty Saxon pennies, which contained as much silver as fifteen of our shillings, and were equal to eight or nine pounds of our present currency; a most extravagant price, which must have involved not only the poor but even those in the middle ranks of life in extreme distress. In a word, we have sufficient evidence that England, which in the time of the Romans was one of the principal granaries of Europe, was so ill cultivated by the Anglo Saxons, that, in the most favourable seasons, it yielded only a scanty provision for its own inhabitants, while, in less propitious years, it presented a scene of the most deplorable scarcity and suffering.†

Rudeness of implements.

When such was the state of Agriculture, we may rest assured that the implements by means of which it was carried on were extremely rude and imperfect. The Saxon husbandmen performed, indeed, the processes of ploughing, sowing, and harrowing; but as all these operations were intrusted to slaves who had little interest in their success, they were executed in a very slovenly and superficial manner. Their ploughs were very slight, and, like those of Shetland at a recent period, had but one stilt or handle. Although water-mills for grinding corn were well known to the Visigoths in Spain, and to the Lombards in Italy, the Anglo-Saxons appear to have been unacquainted with them during the period now under consideration, and had no better way of converting their corn into meal than by grinding it in hand-mills, which were turned by women. By the Laws of Ethelbert, King of Kent, a severe fine was imposed upon any man who should debauch the King's grinding maid. The lands belonging to the Monasteries were by far the best cultivated, because the Secular Canons who possessed them spent some part of their time in improving the soil and tending the progress of their crops. Bede, in his life of Eastawin, the Superior of Wearmouth, tells us that this Abbot, being a strong man and of a humble disposition, used to assist his Monks in their rural

Superior husbandry in Church lands.

* *Reliquiæ Spelmanianæ*, p. 12. Wilkins, *Leges Saxon.* p. 25.
† Spelman, *Gloss. v. Firma.*

* *Liber Niger*, lib. i. c. 7.
† *Hist. Britan. a* Tho. Gale edit. p. 471.

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labours, "sometimes guiding the plough, sometimes winnowing corn, and sometimes forming instruments of husbandry with a hammer on an anvil."*

Improvement under the Normans.

Things were greatly improved in relation to Agriculture under the Kings of the Norman race. Immediately after the Conquest, many thousand husbandmen from the fertile plains of Flanders and Normandy settled in this Island, obtained estates or farms, and employed the same methods in the cultivation of them which had proved so successful in their native Country. The Clergy, too, and especially the Monks, rivalled the Nobility in the art of improving the soil. It was in fact so much the custom for the Regulars of this period to assist in the labours of the field, especially in seed-time, the hay-season, and harvest, that the famous à Becket, even after he was Archbishop of Canterbury, used to sally out with the inmates of the Convents near which he happened to reside, and take part with them in all the rural occupations of Spring, Summer, and Autumn. The XXIXth Canon of the General Council of Lateran, held in 1179, affords a further proof that the protection and encouragement of all concerned in Agriculture were objects of attention to the Church. It is thereby decreed, that "all presbyters, clerks, monks, converts, pilgrims, and peasants, when they are engaged in the labours of husbandry, shall, together with the cattle in their ploughs, and the seed which they carry into the field, enjoy perfect security; and that all who molest or interrupt them, if they do not desist when they have been admonished, shall be excommunicated."†

Similarity of implements

The implements of husbandry were of the same kind, in this period, with those which are employed at present, though some of them were much less perfect in their construction. The plough, for example, had but one handle or stilt, as it is called, which the ploughman guided with one hand, while in the other he held an instrument both for cleaning the share and breaking the clods. The Norman plough had two wheels, and in the light soil, for which it was constructed, was commonly drawn by one or at most two oxen; but in England, as the land is generally more heavy and tenacious, a greater number of cattle was necessary. Their carts, harrows, scythes, sickles, and flails appear, from the figures of them still remaining, to have been nearly of the same form as those which are now used.‡

and of processes to those in modern use.

Although the various processes of husbandry are incidentally mentioned by the Writers of that period, it is nevertheless very difficult to collect from them a distinct account of the manner in which these operations were performed. Marl seems to have been the chief manure in the absence of dung. Summer fallowing of lands designed for wheat appears to have already become a common practice of the Anglo-Norman farmers; for Giraldus Cambrensis, in his description of Wales, takes notice of it as a great singularity in the husbandmen of that Country, "that they ploughed their lands only once a year, in March or April, in order to sow them with oats; but did not like other farmers plough them twice in the Summer and once in Winter, in order to prepare them for wheat." In Mr. Strutt's very curious and valuable Work, we see the figures of several persons engaged in mowing, reaping, threshing, and winnowing; in all which operations there appears to be little that is singular or at all different from modern practice.

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Backwardness of Agriculture in Scotland.

The state of Agriculture in Scotland at the same period must have been very imperfect; for in a Parliament held at Scone by Alexander II., in the year 1214, it was enacted that such farmers as had four oxen or cows or upwards, should labour their lands by tilling them with a plough, and should begin to till fifteen days before Candlemas; and that such farmers as had not so many as four oxen, as they could not labour their lands by tilling, should delve so much with hand and foot as would produce a sufficient quantity of corn to supply themselves and their families. But this law was probably meant for the Highlands and most uncultivated parts of the Kingdom; for, in the same Parliament, a very severe law was made against those farmers who did not extirpate a pernicious weed called *guilde* out of their lands; a regulation which seems to indicate a more advanced state of rural economy.

Progress till the XVth Century.

The next three Centuries present such an alternation of high and low prices, of famines and of excessive plentifulness, that we cannot arrive at any just conclusion as to the ordinary state of Agriculture. But there is reason to believe that, although the progress was slow and frequently interrupted by war and domestic broils, there was, on the whole, a considerable advancement. The importance of having the fields enclosed had been very generally admitted. Even "the feeding lands," says Sir John Fortescue, "are likewise surrounded with hedgerows and ditches, planted with trees, which protect the flocks and herds from bleak winds, and sultry heats."* Summer-fallowing for wheat was practised in the XIIIth Century as much if not more than it is at present. It was then a kind of rule among farmers to have one-third of their arable lands in fallow. In the law book called *Fleta*, composed in the reign of Edward I., very particular directions are given as to the most proper time and best manner of ploughing and dressing fallows. The farmer is there instructed to plough no deeper in Summer than is necessary for destroying the weeds; not to lay on his manure till a little before the last ploughing, which is to be done with a deep and narrow furrow. Rules are also given for changing and choosing seed; for proportioning the quantity of different kinds to be sown on an acre, according to the nature of the soil and the degree of richness; for collecting and compounding manures, and accommodating them to the ground on which they are to be laid; for determining the particular times in the course of the year best suited for sowing the several descriptions of grain; and, in a word, for performing every operation in husbandry, at the best time and in the best manner. In the same Treatise the duties of the steward, of the bailiff, and of the overseer of a manor, and of all the other persons concerned in the cultivation of it, are explained at full length, and with so much good sense that, if they were well performed, the manor could not be ill cultivated.†

Distractions during the latter half of that period.

From the middle of the XIVth till towards the end of the XVth Century, the unsettled state of the kingdom was extremely unfavourable to the interests of Agriculture. The unhappy rustics were not permitted to pursue their toils in peace, but were liable every moment to be called from the plough into the field of battle, by a Royal Proclamation or by the mandates of their

* Wilkins, *Leges Saxon.* p. 3. Bedæ *Hist. Abbat. Weremut*, p. 296.

† *Chron. Gervas.* col. 1400 and 1456.

‡ Strutt, *View of the Manners, &c.* vol. ii. p. 12. vol. I. pl. xxvi.

* *De Laudibus Legum Angliæ*, c. 24.

† *Fleta*, lib. ii. c. 72. 76. 78.

Agriculture. own arbitrary lords. Such multitudes of this most useful order of men actually fell in the course of war, that hands were wanting for the necessary operations of husbandry; a circumstance which led, by very natural steps, to the high price of labour characteristic of the period now under consideration. Many laws were made to reduce wages, to compel persons to assist in the cultivation of the land, and to restrain them from following other occupations. In one of these Statutes it is said that Noblemen and others were greatly distressed for want of farm servants; and therefore it was enacted that "whoever had been employed at the plough or cart, or any other husbandry work, till he was twelve years of age, should be compelled to continue in that employment during life; and that none who had not lands or rents of the value of twenty shillings a year, should be permitted to put any of their sons apprentices to any other trade, but should bring them all up to husbandry."*

Extension of pastures.

These severe laws, while they prove the existence of the evil, are known to have supplied a very inadequate remedy. The scarcity of labourers still continued, and even increased to so great a degree as to produce a considerable change in the application and value of landed property. The Barons, Prelates, and other extensive owners kept large tracts round their castles, called their demesnes, which were cultivated either by their villains, or by hired servants under the direction of bailiffs. But these landholders having diminished the number of their retainers by a succession of wars, and not being able to obtain the assistance of Agricultural labour on reasonable terms, resolved to enclose their lands and convert them into pasture-grounds. This practice became very general about the end of the XIVth Century, and occasioned very loud clamour on the part of those who mistook the effect of depopulation for its cause.

Invectives against enclosures.

John Rous of Warwick was a most violent declaimer against the Nobility and Gentry who enclosed their lands; and a considerable part of his *History of England* consists of the most bitter invectives against them on that account. He calls them depopulators, destroyers of villages, robbers, tyrants, basilisks, enemies to God and man; assuring them at the same time that they would all go to the devil when they died. This zealous opposer of abuses tells us that he presented a petition against them to the Parliament which met at Coventry in the year 1459, without obtaining a favourable hearing, and that several petitions to succeeding Parliaments were equally unsuccessful. But although this innovation in the manner of using land was introduced at first by the scarcity of labourers, it cannot be denied that the humour of enclosing arable lands for pasture was at length carried much too far; and we find, accordingly, that Parliament, at a somewhat later period, deemed it expedient to interpose its authority for the purpose of checking the progress of an evil which threatened the most alarming consequences.†

First restrictive corn-law.
A. D. 1463.

It is remarkable that at the epoch in question, although corn was sometimes very dear, it was also occasionally very cheap. In 1455, wheat was sold in certain places so low as one shilling the quarter. But this cheapness, it has been asserted, was not so much owing to any improvements in husbandry, as to an extraordinary importation of wheat from the Continent in order to procure a supply of English wool. To prevent such excessive influxes, which threatened the ruin of the farmer and excited the most violent complaints, a law was passed, in the year 1463, by which it was provided that no grain of any kind should be imported when wheat was below 6*s.* 8*d.*, rye under 4*s.*, and barley under 3*s.* the quarter. These were then considered such high prices as to call for a supply from foreign parts.*

Continued decline of Agriculture in England,

But the great decrease in the value of land at this period is the strongest proof of the decline of Agriculture. In the reign of Edward III., there are some examples of land being sold at twenty-five years' purchase, which, it is probable, was not much above the common price; whereas in the time of Edward IV., there is the fullest evidence that land had fallen to a value of less than one half. And if Agriculture declined in England in those days, it was still more neglected in Scotland, as the latter Country suffered even more, in proportion to its wealth and population, by long and ruinous wars. The low state of this important Art is manifest from the laws which were made for its improvement. By one of these, passed in 1424, it is enacted that, "ilk man of simple estate, that sould be of ressoun labourers, have either half an ox in the pleuh, or else delve ilk day vii fute of length and vii ou breadth." Another law, in 1457, is thus expressed: "Anent the sawing of quheit, peis, and beinis, it is sene speidful, that ilk man wend with a pleug of viii oxen, shall saw at the least ilk year, ane firlot of quheit, half a firlot of peis, and forty beins, under the pane of x shillings to the baroune of that land that he dwells in. And giff the baroune saws not the said corn in his domainis, he shall pay to the King x shillings."† (in Scotland.)

The Peace which followed the union of the Roses under the family of Tudor was favourable to many of the Arts, and laid the foundations of that improvement which has advanced with little interruption until the present day. But Agriculture did not share in the general benefit. The practice of converting arable land into pasture still continued during the reign of Henry VII. Enclosures were multiplied, demesne lands were extended, till the farms of most of the husbandmen were appropriated to the feeding of sheep; the houses were demolished or allowed to fall into ruins, while a few shepherds supplanted the yeomen, and occupied in some Counties the largest estates with their increasing flocks.

False policy of excessive encouragement of the wool trade.

But the cause most detrimental to Agriculture may be discovered in the restrictions attending the exportation of grain, and the large demand for English wool on the Continent. At a former period the exportation of corn had in certain circumstances been permitted, and its importation regulated by different Statutes; but by these restrictions a discretionary power to dispense with their main provisions was committed to the King, and there is reason to believe that the prerogative was seldom exerted unless for the encouragement of private monopolies, or for giving strength to pernicious restraints. It is true that a law was passed at an early stage of this Monarch's government, for the future support of those houses of husbandry to which, within three years, twenty acres of land had been annexed, and enforced by a penalty of half the rent until the grounds should be again occupied and the dwellings rebuilt. But it was not until it become more profitable to raise corn than to feed sheep,

* *Statutes 7 Henry IV.* ch. xvii.
† J. Rous, *Hist. Ang.* p. 39. 120.

* Stow, p. 398. *Statutes* 3 *Edward IV.* ch. ii.
† *Black Acts*, fol. 7.

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that the plains of England were restored once more to tillage. The immense flocks of twenty thousand and upwards, which by a Statute of Henry VIII. were pronounced illegal, gradually gave way before the dominion of the plough, so soon as the manufacturers of the Netherlands were compelled or induced to remove their establishments to Britain.*

Sir A. Fitzherbert's *Book of Husbandry* A. D. 1532.

The reign of Henry VIII. is distinguished for the first native Work on Agriculture published in England. We allude to the *Book of Husbandry*, written by Sir A. Fitzherbert, one of the Judges of the Common Pleas, and highly esteemed even at the present day, as well for the judicious observations which it contains, as for the liberal spirit with which it is animated. He recommends draining, clearing, and enclosing a farm, and gives many good directions for enriching the soil. Lime, marl, and fallowing are strongly urged. The landlords are advised to grant leases to those farmers who will engage to surround their farms and divide them by hedges into proper enclosures; by which operation, he says, "if an acre of land be worth sixpence before it is enclosed, it will be worth eightpence when it is enclosed, by reason of the compost and dunging of the cattle." From the appearance of this book the revival of rural industry in England may be dated. Fitzherbert's remarks on live stock are excellent, and said to be entirely applicable to the business of grazing in our own times. "An housbande can not well thrive by his corne without he have other cattell, nor by his cattell without corne. And bycause that shepe in myne opynyon is the mooste profytablest cattell that any man can have, therefore I purpose to speake fyrst of shepe." After recording various precepts for "quycksittinge, dychinge, and hedgeying," and "for a yonge gentleman that intendeth to thrive," he gives a "prolonge for the wyves occupation." "She must first make herself and himself somme clothes; and she may have the lockes of the shepe eyther to make blanketts and courlettes or bothe." "It is a wyves occupation to winnowe all maner of cornes, to make malte, to washe and wrynge, to make heye, shere corne, and in time of nede to help her husbande to fill the mucke wayne or dounge cart, dryve the ploughe, to loode heye, corne and such other; and to go or ryde to the market to sell butter, chese, mylke, egges, chekyns, capons, hennes, pygges, gese, and all maner of cornes."

produces a revival.

His Book of Surveying. A. D. 1539.

This Treatise was followed by another entitled *Of the Surveying of Lands*, which has likewise added considerably to our knowledge of rural affairs at that period. He takes occasion to mention the different kinds of commons that were then recognised; describes the sundry species of mills which were used for grinding corn, including also the "quernes that go with the hand;" delineates the various orders of tenants down to bondmen, who in some parts of the Country were not yet extinct; and he concludes his Treatise with an inquiry how to make a township that is worth twenty marks a year worth twenty pounds. His views may be learned from the following extract.

"It is undoubted that to every townshyppe that standeth in tillage in the playne country, there be errable lands to plowe and sowe, and leyse to tye or tedder theyr horses and mares upon, and common pasture to kepe and pasture theyr catell, beestes, and shepe upon; and also they have medowe grounde to get theyr hey upon. Than to let it be knowne how many acres of errable lande every man hath in tyllage, and of the same acres in every felde to chaunge with his neyghbours, and to leye them togyther, and to make hym one severall close in every feld for his errable lands; and his leyse in every felde to laye them togyther in one felde, and to make one several close for them all. And also another severall close for his portion of his common pasture, and also his portion of his medowe in a several close by itselfe, and all kept in severall bothe in wynter and somer; and every cottager shall have his portion assigned hym accordynge to his rente, and then shall nat the ryche man overpresse the poore man with his cattell; and every man may eate his owne close at his pleasure. And undoubted, that heye and strawe that will fynd one beeste in the house will find two beestes in the close, and better they shall lyke. For those beestes in the house have short heare and thynne, and towards March they will pylle and be bare; and therefore they may nat abyde in the fylde before the heerdmen in wynter tyme for colde. And those that lye in a close under a heydge have longe heare and thyck, and they will never pylle nor be bare; and by this reason the husbande may kepe twyse as many catell as he did before.

"This is the cause of this approvment. Nowe every husbande hath six severall closes, whereof iii be for corne, the fourthe for his leyse, the fifthe for his commen pastures, and the sixte for his heye; and in wynter tyme there is but one occupied with corne, and than hath the husbande other fyve to occupy till Lente come, and that he hath his fallowe felde, his leye felde, and his pasture felde all sommer. And when he hathe mowen his medowe, than he hath his medowe grounde, soo that if he hath any weyke catell that wold be amended, or dyvers maner of catell, he may put them in any close he wyll, the whych is a grete advantage; and if all shulde lye common, than wolde the edyche of the corne feldes, and the undermath of all the medowes be eaten in x or xii dayes. And the ryche man that hath moche catell wold have the advantage, and the poore man can have no helpe nor relefe in wynter when he hath moste nede; and if an acre of lande be worthe sixe pens, or it be enclosed, it will be worth viii pens whan it is enclosed, by reason of the compostying and dongying of the catell that shall go and lye upon it bothe daye and nyghte; and if any of his thre closes that he hath for his corne be worne or ware bare, than he may brake and plowe up his close that he had for his leyse, or the close that he had for his commen pasture, or bothe, and sowe them with corne, and let the other leye for a tyme, and so shall he have always reish grounde, the whych wyll beare moche corne with lytel donge; and also he shall have a grate profyte of the wod in the heydges whan it is growen; and not only these profytes and advantages before said, but he shall save moche more than all these, for by reason of these closes he shall save mete, drinke, and wages of a shepeheerde, the wages of the heerdman, and the wages of the swineherde, the whych may fortune to be as chargeable as all his holle rent; and also his corne shall be better saved from eatinge or destroyinge with catell. For doubt ye nat but heerdmen with their catell, shepeherdes with their shepe, and tieng of horses and mares, destroyeth moche corne, the which the heydges wold saue. Peradventure some men wold say that this shuld be againste the commen weale, because the shepeherdes, heerdmen, and swyneherdes shuld then be put out of wages. To that it may be answered, though these occupations be not used, there be as many

* Henry, vol. xii. p. 258.

Agriculture. new occupations that were not used before; as getting of quicksettes, dyching, heydging, and plashing, the whych the same men may use and occupy."

It will be enough to mention the *Five Hundred Points of Husbandry*, by Tusser, published in the year 1562; the *Whole Art of Husbandry*, by Googe, which appeared about sixteen years later; the *Jewell House of Art and Nature*, by Sir Hugh Platt, and several other performances of a similar nature, the object of which was to enlighten the farmers of the XVIth Century. But the attention of the reader ought to be more particularly drawn to a Treatise by Sir Richard Weston, on the *Husbandry of Brabant and Flanders*, for in it may be detected the seeds of the numerous improvements which have since been effected in this Country. Western was Ambassador from England to the Elector Palatine and King of Bohemia; and during his residence on the Continent he became acquainted with the use of clover and probably also of turnips, as a valuable species of food for cattle. His directions for the cultivation of the former, though objectionable in some points, are yet so good as to prove that they must have been derived from experience. It thrives best, he alleges, "when you sow it on the worst and barrenest ground, such as the worst of our heath-land here in England. The ground is to be pared and burnt, and unslacked lime must be added to the ashes. It is next to be well ploughed and harrowed, and about ten pounds of clover seed must be sown upon an acre, in April or the end of March. If you intend to preserve seed, then the second crop must be let stand till it come to a full and dead ripeness; and you shall have at the least five bushels per acre. Being once sown it will last five years; and then, being ploughed, it will yield two or three years together, rich crops of wheat, and after that a crop of grass, with which clover seed is to be sown again."

Tusser.

Googe.

Sir Hugh Platt.

Sir R. Weston.

To Blythe, who published in the time of the Commonwealth, is due the first hint of a rotation in crops, or at least of the advantage which may be derived from alternating clover and turnip with corn on the same field. All the manures now in use were well known in his days, especially lime, on which he set a great value as an ingredient of fertility. A great improvement had likewise taken place in the implements of husbandry. A machine is mentioned which ploughed, harrowed, and sowed at the same time. The following note will amuse the curious reader. "It is not many years since the famous city of London petitioned the Parliament of England against two nuisances or offensive commodities which were likely to come into great use and esteem; and that was Newcastle coal in regard of their stench, and hops in regard they would spoyle the taste of drink and endanger the people."

Evelyn.

The names of Hartlib, Markham, Mascall, Ray, and Evelyn are familiar to every reader on Agriculture, or on rural economy at large. The *Sylva* and *Terra*, of the last of these authors, still retain a merited reputation. In fact, the improvement which took place in the management of land in this Country, from the reign of James II. down to the middle of the last Century, was not very great; and hence the writers on husbandry between the period of the Revolution and the accession of George III. are not, generally speaking, superior to those who published nearly a hundred years before them. The chief exception to this remark applies to Jethro Tull, a gentleman of Berkshire, who introduced the practice of drilling wheat and other crops, about the year 1701, and who, thirty years afterwards, put forth a book on *Horse-hoeing Husbandry*. From an unhappy tone in his manner of writing, as well as from an undue degree of opposition to the usages of his day, his Work made less impression than it ought to have produced in an Agricultural Country. Hence it was not until 1780 that the present method of drilling and horse-hoeing turnips was admitted into Northumberland; at which time it was borrowed from Scotland, where the farmers had the merit of first adopting Tull's management of this valuable root, and whence it made its way but slowly into the more Southern parts of the Island.

Jethro Tull.

Agriculture.

Agriculture of Scotland.

In regard to the Agriculture of North Britain, it has been suspected that the accession of James I to the English Crown was unpropitious to it in the first instance, not only because many of the Nobility followed their Sovereign, and were thereby led to neglect their native soil, but also because the increased expenditure of the landlords in a more wealthy Country give rise to various exactions on the poor tenants. The residence of Cromwell's army, however, Northward of the Tweed, during several years of the Protectorate, did more than counterbalance the evils arising from the absence of a Court. The soldiers, being chiefly English yeomen, were necessarily well acquainted with the practice of husbandry; and, like the Romans of old, they showed themselves ready to enlighten the people whom they had subdued. Hence it has been remarked that the low country districts were, at the eve of the Restoration, in a higher state of improvement than they had attained since the death of Alexander III. In the Counties of Lanark, Renfrew, Ayr, and Kirkcudbright, the rents of various estates were higher than they were seventy years afterwards; a fact which may be accounted for by a reference to the disturbed condition of the Kingdom under the last two Monarchs of the Stuart dynasty. A succession of bad seasons immediately after the Revolution, increased the distress of the Scottish farmer, which was still further aggravated by the insurrections of 1715 and 1745. After the last of these attempts to restore the exiled family had exhausted the zeal and means of the Jacobites, the Government of the Country was consolidated, and the sources of her improvement again opened up. Since that period the husbandry of Scotland has advanced regularly and steadily, so as now to bear comparison, local circumstances considered, with that of any Nation in Europe. Since the year 1789 in particular, when the contest with our American Colonies was terminated, the interests of Agriculture have been promoted with astonishing success; and while the rent-rolls of proprietors have been doubled, tripled, and even quadrupled, the condition of the tenants and of the peasantry in general has been meliorated in a corresponding degree.

Improved under the Protectorate.

Declines after the Restoration.

Gradually improved since 1745.

We believe the first Association for the improvement of rural affairs was formed in Scotland in the year 1723; at which time a number of landholders constituted themselves into a Body, under the title of the *Society of Improvers in the Knowledge of Agriculture*. The *Select Transactions* of this fraternity were published in 1743, and exhibit an accurate acquaintance with the best modes of conducting the various processes of farming at that time pursued in the most enlightened parts of Europe. This example was followed, at a more recent date, by the *Bath and West of England Society*, and by the *Highland Society* of Scotland. The *National Board of Agriculture* derived its origin from

Agricultural Associations

Agriculture. similar views: but as such Institutions are usually better conducted by the voluntary labours of individuals than by the official Members of Government, the Crown has for some time withdrawn its patronage. The same object is perhaps equally well accomplished by the general circulation of knowledge through the medium of the Press. The numerous *Farmers' Magazines* and *Agricultural Journals*, while they attest the interest which is taken in this important pursuit, make known over the whole Empire the result of every experiment; for, it is worthy of remark that, in this branch of industry, there are neither secrets nor privileged discoverers; every one communicating to another whatever new views accident or research may have brought to light.

and publications.

Recent state Agriculture on the Continent of Europe.

We shall conclude this Historical sketch with an extract from a communication to the *Quarterly Journal of Agriculture*, relative to the recent condition of husbandry on the Continent of Europe. The author, Mr. Boswell, had just finished an extensive tour in France, Holland, Swisserland, Italy, and Spain, and as he appears to possess a practical knowledge of the subject on which he writes, his remarks are not without considerable value. "That the Agriculture of Britain," says he, "is superior to that of the Continent, or indeed, of the whole World, every one must admit who knows any thing of the matter; but to explain the causes of this superiority may not be a matter of so easy discovery. Our climate, at least in Scotland, is bad; our soil is by no means uniformly fertile, and there are other causes which at first sight seem to put a *veto* on improvement in the Art of Agriculture; yet with all these disadvantages to contend against, it cannot be denied that we have risen superior to all the World. Of course I make this broad assertion on the authority of those who have visited the other quarters of the Globe. For my own part, it has been my lot to see a considerable part of Southern Europe, and comparatively speaking I am safe in saying that I have never yet seen a well-drawn furrow or drill by a foreigner. I make use of the word foreigner, because in visiting Xeres de la Fronteira, in the Winter of 1809, I was shown a very beautiful crop of turnips with drills drawn in the most masterly style; but these were found on inquiry to have been made by East Lothian ploughmen, brought to the Peninsula by my kind host Mr. Gordon, whose exertions for the improvement of that part of Spain were neither known nor rightly appreciated by that stupid and tyrannical Government. In making this statement some may set me down as one of those prejudiced people who in a John Bull sort of way will not allow any merit to exist out of this little Island. But I wish it to be clearly understood that my remark is intended to apply only to the department of Agriculture, or rather to the operations of the ploughman, for I have frequently seen more beautiful specimens of spade culture abroad than in our own Country: this, however, more properly belongs to Horticulture. On the Continent their implements are so defective that it is impossible the work can be well performed; hence, wherever there is a dense population, and the *petite culture*, as the French call it, is followed, there one commonly finds spade-work exceedingly well done, particularly where the vine is cultivated: but the moment they farm on a large scale it is execrable. I scarcely know where to say that the Agriculture is the worst. It seems to be in an inverse ratio of the goodness of the climate and fertility of the soil, that the farming is bad. In the States of the Pope, where the soil and climate cannot be excelled, I think I may say it is the worst. In all my wanderings, with one solitary exception, at Hofwyil near Berne, I may truly say I have never seen a plough! A clumsy thing made of a few pieces of bent wood, fastened together with one or two hobnails, is used for tilling, and although this implement varies in form in different Countries, it is every where equally remote from the plough of this Country, constructed in the manner which Science points out to be the best. With such a tool as I have described to stir the soil, it is almost superfluous to say that the work more resembles the pastime of a herd-boy, or pigs hunting for trumes, than the work of a Norfolk or a Scotch ploughman. Over a great part of the Continent, the harrow is an implement not even known. In some parts of Flanders, on the Rhine, in Prussia, and Germany, they use what they call a harrow, a small triangular frame of wood into which are inserted a few wooden pins. Wretched, however, as it would be esteemed by our farmers, it is a refinement in Agriculture not known on the fertile plains of Spain or France, on the wide-extending Campagna di Roma, or in the farming of Calabria, where they either plough down the seed, or not unfrequently cover it by throwing earth upon it with an implement in form between a hoe and a spade, leaving the ground, when the operation is finished, in long beds, such as those in which the gardeners grow onions.

"The best farming on the large scale which I have seen is in Flanders, near Waterloo, and in the adjoining part of the Country; but it is clumsy, and performed with very defective instruments. In Tuscany the soil is by far the best cultivated; but it is generally speaking in small holdings, and the greatest part is done by manual labour; although they also use the plough a good deal, making the oxen work close to the rows of vines, which border every field, and which they are prevented from eating by a slight muzzle of basket-work hung in their noses. The Tuscan plough is not nearly so rude as that made use of in many other Countries; and the Tuscan Agriculturists are even acquainted with our method of opening drills, putting in manure, and then closing them with the plough. Taking you Northward by a very rapid journey from this part of Italy to Berne, I shall say a few words respecting Hofwyil. Here the British Agriculturist, who visits the farm of M. Fellenberg, is surprised to find not only all the newest and best improvements in Agricultural implements, as used in Great Britain, but many invented by himself, and constructed at Hofwyil, which surpass in simplicity and beauty the best I have seen at Holkham. I was particularly pleased with a corn-driller, which had a dial and index to show the ground gone over; thus possessing the double advantage of showing the work done by the horses, and the quantity of seed used per acre. This farm is like the most beautiful garden as to neatness, and being free from weeds. All that is done by the spade and hoe is capital, there can be no better work. But if I, who was well acquainted with the farming of East Lothian, felt the greatest surprise on first seeing the correctness, I might say the mathematical precision of the drill-husbandry of Holkham, what would be the feelings of M. Fellenberg, if he could see and compare that *ne plus ultra* of good workmanship with the bungling performance of his own people, provided as they are with such admirable tools to work with?

"There is one feature in the Agriculture of the Con-

Agriculture. tinent which ought to be adverted to. In this Country, when we read an account of any other part of the World, and are told that it is all enclosed, we naturally imagine to ourselves cattle feeding quietly, or corn growing in separate fields. But how sadly disappointed is the British traveller to discover the mistake into which he has been led, and to find that the enclosures, where there are any, have been formed, not to keep in, but to keep out cattle. If one of our Countrymen land in Holland, and behold the beautiful meadows full of the finest cattle, he is led to think that things are not very different from what he has been accustomed to at home. But he must very soon change his opinions, for he quickly gets into a Country where there is nothing but the soiling system known or used; and if he proceed Southward he will not see another animal in a field, till, after a journey of hundreds of miles, he reach the Pontine Marshes between Rome and Naples. In some places, indeed, they drive them out in the daytime to pick a few weeds in the lanes, or on the outsides of the enclosures, which are generally a ditch and a bank of earth, made very deep, and smoothed with the back of a spade when the mud is wet; and in some mountainous districts, such as the Tyrol, one sees herds browsing on the sides of the steeps, but it is generally at such a distance that, except to fill up the beauty of the landscape, the sight of them is no way useful to the inquiring Agriculturist. Sometimes, late in the evening or very early in the morning, one may, from the window of a village inn, get a passing view of the kine; and most peaceful is the sight, while the varied sound from the bell, or rather canister, which hangs appended to the neck of each, forms most appropriate and pastoral music. But on descending again to the plains, the soiling plan is once more found to be the only one of treating live stock; a method which, however well it may answer as to gaining dung, is certainly bad for the cattle; for I have observed that where the soiling system is followed, they are universally poor-looking, knock-kneed creatures of very small size. In Holland and in the Pontine Marshes, on the contrary, where they feed on the sward, they are very fine.

"On comparing the Agriculture of the Continent with that of this Country, we are indeed struck with the miserable manner in which the operations of the plough and harrow are conducted; but the great deficiency is a total ignorance of what we call green-cropping on the large scale. It is true that both potatoes and turnips are used in the different Countries; but I have never seen them properly cultivated, and, consequently, never approaching to a full crop. In Flanders, Prussia, Germany, and in the Swiss cantons, there is no one who holds land but grows a portion of potatoes: but they are planted either by the hand on a flat surface, or put in with a spade, so close that, instead of horse-hoeing, it is wonderful to me how they can get them hand-hoed; the consequence of which is that the potatoes never reach the size of a common egg. But the measure of bad farming is filled up by the rude method adopted for thrashing out the corn, still making use of cattle or horses, at least in all the Southern parts of Europe, to tread it out as we read in the Scriptures."*

* *Quarterly Journal of Agriculture*, May, 1828. vol. i. p. 189. &c.

On the Theory of Agriculture.

Agriculture. Customary faults of Agricultural Theories.

Although Husbandry is an Art which has been carried on from the earliest Ages by a greater number of people than are concerned in any other, yet even at this advanced period, the speculative Agriculturist may in some measure be viewed as remaining without any fixed principles on which to found his precepts. Instead of resorting to practice, and thence forming a satisfactory Theory, writers on Agriculture, in numberless instances, have amused themselves without instructing their readers by presenting abstract opinions on this important subject; not reflecting that every kind of Theory which is not built upon extensive experience, is fallacious and sometimes positively absurd. According to the method adopted by these authors, he who argues most ingeniously must necessarily be regarded as coming nearest to the Truth; and his doctrine will, therefore, be considered as the standard until some other shall start up, whose eloquence may prove more persuasive, and whose notions may be held more plausible. This has been the fate of all Philosophical conclusions on this subject, since the earliest times. For example, how numerous and diversified are the sentiments of Theorists respecting the food of plants; although it is a certain fact that the most acute Naturalist can no more account for the germination of a single grain of corn, than he can explain the mysterious grounds on which he himself enjoys a rational existence.* Without, therefore, stopping to inquire whether the gaseous substances, oxygen, hydrogen, in their separate state, or a combination of them in the form of air and water, or the oxides of those metallic bases which give rise to the various earths, constitute the *pabulum* of the vegetable species, it may be remarked that the dullest farmer knows sufficiently that if he drains, cleans, and manures his land in a proper manner, it will yield him as good a crop as the soil is constitutionally capable of producing, provided Physical circumstances, such as heavy rains, excessive droughts, or furious winds do not prevent Nature from discharging her usual functions. As we neither have the command of the essential elements which minister to vegetation, nor can order the Sun to display his beams, nor the atmosphere to afford genial gales, nor the clouds to drop refreshing showers, little benefit could accrue to the operative husbandman were even the curtain of Nature drawn aside, and our eyes permitted to roam at large over a field which may justly be regarded as forbidden to Man. Under these impressions we are inclined to consider all abstruse disquisition, respecting the Chemical properties of Matter, the Physiology of plants, and the structure of their several organs, as rather out of place in a Treatise on Practical Agriculture. Regarded as a Science, indeed, there is no absurdity in connecting it with every other branch of investigation which has the analysis of matter for its object. Nay, in a certain sense it might be made to derive light and assistance from Astronomy, Anatomy, Mechanical Philosophy, and Pharmacy; for the cultivator has to study the seasons, the corporeal qualities of the horse, the composition of forces in the application of its strength, and the effect of drugs in repelling its disease. But it is obvious that similar argument might be used for the necessity of scientific knowledge in all the other departments of human industry, inasmuch as every

* Brown on *Rural Affairs*, vol. i. p. 69.

Agriculture. Art that is practised, even by the most ignorant operative, has a dependence more or less remote upon Philosophical Principles. Besides, Agriculture, above all other Arts, is founded on experiment, and has uniformly derived its most important improvements from trials judiciously made and carefully repeated. The man of Science, in this case, only follows and discovers, or endeavours to discover, a reason for the successful result which has been already ascertained; and, by generalizing the truth implied in some particular fact, he perhaps aids the application of it to a greater variety of objects. If there be any branch of Physical research which has a peculiar claim to the attention of the Agriculturist, it may be conceived that this distinction belongs to Chemistry; the means supplied by which are so efficacious for analyzing soils, detecting the qualities of manure, and determining the composition of the vegetable products. But it is well known that very little reliance can be placed on the best-conducted Chemical process for ascertaining the properties of land, or its fitness for particular crops. The eye of an experienced farmer is much more to be relied upon in the selection of a field, than the report of the ablest Lecturer who ever used a test, or presided over a crucible. In many instances it would not be more hopeless to undertake the estimate of a man's temper and talents from the weight of his body or the tint of his complexion, than it is to fix the precise qualities of the several portions of a farm, by subjecting a specimen of the soil to the operation of an acid or an alkali.

Causes of the failure of speculation.

We mean it not to be inferred from these observations that the Principles of Science are inapplicable to the advancement of Agriculture. On the contrary, we are satisfied that every step which is gained by the Philosopher in his acquaintance with the composition and powers of Matter, whether in its solid or gaseous form, will ultimately produce an effect in extending the empire of Man over the elements of Nature, and thereby add to his wealth and comfort. Our remarks have no other object than to establish the important maxim, that the labours of the husbandman are directed by Principles so simple that his success will never be found impeded by his ignorance of the refined disquisitions of the Physiologist or Chemist. For example, were he at a loss to determine the effect of bone-manure, of rape-cake, of nitre, or of kelp on a piece of land, he could not have his doubts resolved by consulting the most learned Work on the Philosophy of Agriculture; because the action of these substances depends entirely on circumstances which cannot be brought under any general description or reduced to one rule. The rape-cake might suit one part of the field, and the nitre might answer better for some other part of it; and yet so far as Chemical analysis could proceed in deciding the question, the soil of the whole would probably be declared homogeneous and fitted for one system of management. The points which give the distinguishing character to a section of arable ground, must in general be sought for under the surface. The subsoil has a great influence in aiding or counteracting the effect of manure, and in requiring a greater or less quantity of labour; perhaps the Geological structure of the surrounding platform interposes an energy which may assist in defeating or promoting the intentions of the cultivator; and the mineral bodies which lurk in its recesses may contribute their share also in covering the face of the country with a plentiful harvest, or in blasting it with sterility. Hence it is universally admitted that no man is so unlikely to prosper as a speculative farmer. The failures which have almost constantly ensued among Scientific Agriculture. projectors, who set at naught the lessons of experience, have created in many parts of the country an undue prejudice against all change, even when it wears the aspect of a manifest improvement. To the same cause must be ascribed the little success which in most cases attends the processes of gentleman-farming; for, besides the greater expense incident to the different style of living among the servants, there is a natural tendency in every educated mind to promote the Arts by the aid of experiment.

Three safest Principles.

The safest Theory of Agriculture, therefore, is that which comprehends those Principles only which have been confirmed by observation and long practice; such, for example, as that the soil should be well drained, or kept free from all superfluous moisture; secondly, that it should be kept clean or free from all noxious weeds; and thirdly, that it should be kept rich, or in other words, that every particle of manure which can be collected ought to be applied, so that it should be retained in a state capable of yielding good crops.

1. Draining.

In the first place, the necessity of preserving the land in a dry state is so obvious, that few arguments will be required in support of this preliminary Principle. When ground is allowed to remain wet, which may be occasioned by springs in the undersoil, or by rain-water stagnating on the surface, the earth becomes sour and thereby extremely unfavourable to the growth of plants; and often in the first instance prevents either ploughing or harrowing from being successfully accomplished. Under such circumstances the young plants, whether of corn or grass, appear yellow and sickly, and never assume that vigorous aspect which they exhibit in fields properly drained. Besides, manure fails to produce its wonted effect when the land is drowned by water from above or from below. In fact, without attention to this essential operation, neither can arable land be perfectly managed, nor can good crops be raised. Perhaps the progress of farming in any particular country may be more correctly estimated by the care bestowed upon drainage than by any other mark whatever.

2. Weeding.

In the second place, the benefit derived from keeping the soil free from weeds is equally beyond dispute. Weeds, it has been remarked, whether annual or perennial, may be regarded as preferable creditors of the land, who will reap the first advantage of manure if allowed to remain in possession; their removal, therefore, forms an important object of the husbandman's attention. Without detailing in this place the most effectual means for effecting that purpose, it may be asserted, that in proportion to the success which follows the use of the means employed, so will the goodness or badness of the crop be determined. If the nutritive powers of a field be exhausted by weeds, or by such plants as the soil naturally produces, it is impossible that the artificial plants can prosper. It rarely happens indeed that the natives are altogether extirpated, even by the most sedulous farmer; but it is true, nevertheless, that upon the smallness of their number depends the amount of the return which the Earth makes to Man for the toil bestowed upon its cultivation.

3. Manuring.

In the third place, the necessity of restoring to the land, in the shape of manure, the fertility or powers of production, drawn from it by a succession of crops, is acknowledged by every one, except the disciples of Jethro Tull, if there be any of that School now remaining. Manure, in fact, is the most powerful agent in the hands

 of the farmer; and the attention bestowed upon collecting, preparing, and applying, constitutes an important branch of the Art which he practises. Perhaps in the practical details connected with this general Principle, Agriculturists are more deficient than in the duties which respect the two others; and here the advantages of Chemical knowledge will be recognised by many who, on the whole, are not friendly to its more speculative tenets.*

Obvious necessity of tillage. In these fundamental Principles we have omitted the operations of tillage, because the veriest Savage is aware that the surface of the ground must be scratched before the seed is deposited into it. An expert farmer is convinced that before a piece of land can be expected to put forth its strength, it must be well pulverized, and exposed to the action of the sun and air; but as this is one of the processes which must be taken for granted, and belongs rather to the Practice than the Theory of Agriculture, we shall proceed at once to discuss the more important parts of the subject on which we have entered, beginning with a consideration of the different kinds of Soil.

Soil.

Composition and formation. Soil may be defined to be that layer of loose earthy matter which constitutes the upper covering of the Globe, affords a stratum to the roots of innumerable tribes of vegetables, and supplies them with nourishment to promote their growth and bring them to maturity. It consists of the primitive earths which enter into the composition of the prevailing strata or rocks, from the disintegration of which it is obviously formed. The succeeding layer on which the vegetable Soil reposes, whatever be its nature, whether it be composed of less coherent or of more solid materials, is usually distinguished by the name of undersoil or subsoil. We have said that the upper coating, which ministers to vegetation, is derived from the decomposed ingredients of the rocks or strata on which it rests, or of those in the immediate neighbourhood, the *débris* of which is conveyed by means of water. The formation of Soil is, indeed, a beautiful process carried on by Nature, and is accomplished by the combined influence of moisture and temperature on the rocky girdle of the Earth. The changes which take place in this Physical metamorphosis succeed each other with more or less rapidity, according to the nature of the rocks and the power of the agents which operate in their decomposition. In a warm country and moist climate where vegetation is vigorous, it proceeds with astonishing celerity; but in the colder regions of the Earth it advances with slower and more progressive steps. But whatever may be its progress, the hardest rocks, as well as those of less durable and less coherent materials, are subject to disintegration and decay, contributing, as they dissolve, to the formation and increase of Soil.

Progress. By observing what is daily taking place around us, it is not difficult to trace at least the first steps of this process, by which in the course of Ages the hills are lowered and the valleys are exalted. A bare rock when it is uncovered, or a mass of stone which has been lately dug from the quarry, when fully exposed to the air, soon loses its fresh appearance and assumes a different aspect. When this change is investigated it is found that the surface of the stone is covered with a thin crust, of a substance very different from the stone itself. A closer inspection shows that this crust is a vegetable production belonging to the tribe of plants known by the name of *lichens*, and supposed, perhaps from ignorance or the want of means to examine them, to be less perfect than other plants. The seeds of course are extremely minute, easily wafted about by the wind, and floating in the atmosphere attach themselves most readily to those bodies which are somewhat moist. Porous rocks, which are most apt to absorb moisture from the Earth or from the Air, are the first on which lichens make their appearance. By means of this vegetable covering, a larger portion of moisture is absorbed, and a smaller portion of what rises through the rocky substance from the Earth is lost by evaporation: this affords additional nourishment and increases the power of vegetation. A thin layer is soon detached from the surface of the rock and reduced to the earthy form. The first vegetable productions, in the change of the seasons, decay; and hence the first thin stratum of Soil is formed by the decomposition of the vegetable matter and the disintegration of part of the mass of stone in which it was produced. Plants of a larger size and more vigorous growth, whose seeds are carried about in the air, find a fit receptacle in this mixed mass for their vegetation and growth. They in their turn decay, and contribute a fresh portion of vegetable substance, while another accession of earthy particles, derived from the stone, is made to the general mass. Insects and worms which make their abode in the earth or in plants, in the progressive changes to which they are subject and in the various stages of their existence, deposit animal remains in the places which they frequent; and these also serve to increase the quantity of organized matter in the new Soil. Tracing the operation of these causes in the production of fertilized earth, we see the manner in which the surface of the ground is prepared for the reception of innumerable species of plants.

How regulated. Every kind of rock even of the hardest and densest nature is subject to this change. The purest rock crystal when exposed to the weather is deprived, in no long period, of its brilliant lustre and fine polish; but the extent and rapidity of the change, we need not remark, correspond with the nature of the rocky substance and the heat and moisture of the climate. In the warmer regions of the Earth the surface of a bare rock is soon converted into friable earthy matter, covered with verdure and clothed with trees; but in colder climates, as has been already remarked, the process is slower as well as more limited. The vegetables which spring up are of smaller size as well as of more tardy growth, and thus afford a more scanty contribution to the formation of Soil.

Different modifications. It is obvious from what has been just stated, that the diversity of earthy matters contained in the Soil must depend on the constituent parts of the rocks from which it is derived. Rocks in which the prevailing ingredient is silicious earth, afford a sandy Soil; those rocks, again, in which alumina, or pure clay, predominates, yield a clayey Soil; while calcareous earth abounds in the Soil which is formed of the detrition or decomposition of limestone rocks. But the Soil formed by this process of disintegration and Chemical affinity, does not always remain on the spot where it is at first deposited. On the contrary it is carried by floods from the higher to the lower grounds, where it is gradually lodged, and on which, in a succession of Ages, it forms a thick bed. When the earthy matters are swept away by rivers with a slow current, they are deposited on their flat banks or at wide estuaries. In this way some of the richest Soils have been formed. The fertile lands at the mouth of the Nile, of the Po, of the Thames, and the Forth pre-

* Brown on *Rural Affairs*, vol. i. p. 72.

sent examples of this result. Gravelly soil, on the other hand, draws its origin from those rocks whose lofty precipices are exposed to the weather; but especially from such rocks as have many fissures and cavities, and thereby retain water in their bosoms. This water when it is near the surface is frozen in Winter, and by its expansive force when passing into ice, separates and throws down immense fragments. These masses, broken in their fall, are reduced to pieces of still smaller magnitude by the current of rivers, or the agitation of lakes through which they are sometimes carried by the rush of a mountain stream. In the progress of those changes which the face of the Earth every where exhibits, the river changes its course, the sea recedes or advances upon the land, the lake is dried up, and the bank of gravel becomes dry ground. The seeds of vegetables fall on its surface, grow up, and decay; these are succeeded by other generations which run the same course; a portion of earthy matter is obtained from the stones on which the vegetable remains are deposited, and, being mixed with the loose fragments, form at length a Soil which invites the culture of the husbandman.

Effects produced by water.

A moist climate and water stagnating in low grounds have a powerful effect in modifying the Soil. In elevated situations the chilling influence of cold permits only plants of a coarse and hardy character to come to maturity; when they die the same causes prevent or retard their decomposition; and in such places the Soil consists of a mass of half-decayed roots and stems of different species of heath and sedge-grass, with which it is almost entirely occupied. This is the origin of moorish Soils. In places, again, where water lodges permanently, a different race of plants is produced. The bog-moss, or *Sphagnum palustre*, first makes its appearance; a new race of the same species succeeds; other species and plants of a different character find a convenient station in the floating mass; and from the accumulation of innumerable generations of various kinds of vegetables in a state of imperfect decomposition, peaty or mossy Soil derives its origin.

Occasional ingredients of Soil.

Besides the ingredients already mentioned, which may be considered as the base of different Soils, other substances enter into their composition. Some of these (as magnesia, which is sparingly met with in Soils, and contain other metallic substances with which they are impregnated) are understood to have originally existed in the rocks from the disintegration of which the land has been formed. Saline minerals, too, which are sometimes found in cultivated grounds, have the same origin, though they are occasionally deposited by the water of springs as it filtrates through the Soil. The stratum which immediately supports the surface layer in which vegetables grow, is distinguished, as we have said above, by the name of subsoil. It sometimes happens that this undersoil is composed of the rock which furnished the materials for the Soil itself; but it more frequently consists of a bed of gravel, or clay, or sand. A knowledge of the nature of the subsoil is of no small consequence in conducting improvements in Agriculture. It is often the best guide in draining; and in the operation of tillage, when it is within reach of the plough, it may be avoided or partially turned up, as the ingredients of which it is composed when mixed with the Soil are found to be beneficial or otherwise.

Classification.

Hence it appears that Soils may be classed under the several heads of clayey, sandy, gravelly, and peaty or mossy. There is a fifth, which, from its quality, has been denominated loam, and from its history or origin has got the name of alluvial. The principal of these, as we have already suggested, are from the depositions of rivers or of the sea, and are generally rich clays fully impregnated with animal matter in a state of complete solution. Peat, by good management, has sometimes been brought to the condition of loam, and rendered extremely well suited to the culture of what are called the tuberous-rooted plants. It is dark in its colour like the richest vegetable mould, and to the inexperienced eye may pass as such; but still, unless greatly corrected in its texture by the application of the firmer earths, it is found upon trial to be porous and loose, too easily saturated with moisture and too easily freed from it. In this improved state, however, it will yield bulky crops of oats and barley, although the quantity of grain does not always correspond to the weight of the stem or the quantity of the straw.

Uselessness of a more Scientific nomenclature.

The simple nomenclature just given is perfectly intelligible to the practical farmer, although, perhaps, in a Scientific point of view, it might be rendered more complete by adopting the language of the Schools. The clayey, sandy, gravelly, and peaty soils might be termed *genera*, and again divided into *species* and *varieties*. But it is thought better, in the mean time, not to disturb the ordinary speech of the fields and farm-yard. As our knowledge of the composition of Soils increases, we may hope to attain a more scientific nomenclature founded on that knowledge; but nothing of this kind that has yet been attempted can be regarded in the smallest degree as a substitute for the apparently inartificial divisions of the practical husbandman. He chiefly regards Soils with reference to their fertility and the means of cultivating them; and if they are not classed conformably to these views, the arrangement will fail in the main purpose contemplated. Some continental writers of eminence have adopted a very complex system of terms as applicable to the different kinds of land; but they are such as the practical farmer will at once perceive to afford no assistance so far as regards the details of his business. What, for example, should we think of a Soil said to belong to the class *Secondary*; of the order *Earths with organic remains*; of the genus *Coal*; of the species *Pyritic*; of the variety *Black*; and of the sub-variety *Moist*? Such a nomenclature may amuse in the Study, but can direct to no useful practice out of it. Some writers on English Agriculture, more practical than speculative, have, on the other hand, deviated into an error not less perplexing than that now alluded to: for, by an unnecessary mixture of local descriptions and phrases, they have rendered their Works almost unintelligible to those who live beyond the confines of a particular district. They have moreover confounded genera, species, and varieties. Garden-mould, for instance, is given as a distinct division of Soil, in the same sense in which clays, sands, and gravels are said to be so. But garden-mould is merely loam, which, as has been already observed, is included in one or other of the classes above-mentioned. Chalk, too, is described as a separate class. But chalk, as every one knows, is the subsoil and not the Soil: and we may assert that in Countries where this formation exists, no Soils are to be met with which may not be comprehended in the divisions already given, accor[illegible] clay, gravel, or sand predominates in their compo[illegible]

Occurrence of vegetable and animal matter.

We have said that Soils are principally composed of the comminuted earths, which form the substance of the

* *Quarterly Journal of Agriculture* vol. i. p. 31

rocky masses which are observed to encircle the Globe. These are silica, alumina, lime, and magnesia, which are sometimes found in a pure state, but more frequently combined with acids, alkalis, and oxygen, one of the component parts of atmospherical air. Vegetable and animal matter, too, in a state of decomposition, forms an essential ingredient in all good Soils. The former exists in very different states, containing a large proportion of carbonaceous substance, and yielding no volatile alkali. It is the chief ingredient in peats, and is abundant in all rich moulds. The state of animal matter in the Soil is as different as the substances from which it is obtained. It usually contains less carbonaceous matter than vegetable substances; and when exposed to heat, ammonia or volatile alkali, and carbonic acid. It is abundant in Soils to which manure has been lately applied.

Minuter distinctions.

It is evident, therefore, from what has been said respecting the production of Soils from rocks, that there must be at least as many varieties of Soil as there are species of rocks exposed at the surface of the earth. In fact there are many more. Independently of the changes produced by cultivation and the exertions of human labour, other materials of strata have been mixed together and transported from place to place by various great alterations which have occurred in the system of our Globe, and by the constant operation of water. The term sandy, however, should not be applied to any Soil which does not contain seven-eighths of sand: sandy Soils that effervesce with acids, should be distinguished by the name of *calcareous* sandy Soils, to distinguish them from such as are silicious, and which do not effervesce with acids. The term *clayey* should not be applied to any land which contains less than one-sixth of impalpable earthy matter, not considerably effervescing with acids; while the word *loam* should be restricted to Soils containing at least one-third of impalpable earthy matter copiously effervescing with acids. A Soil to be considered as *peaty*, ought to contain at least one-half of vegetable matter. In cases where the earthy part of a Soil evidently consists of a decomposed matter of one particular rock, a name derived from the rock may with propriety be applied to it. Thus, if a fine red earth be found immediately above decomposing basalt, it may be denominated *basaltic* Soil. If fragments of quartz and mica be found abundant in the materials of the Soil, which is often the case, it may be denominated *granitic* soil; and the same principles may be applied to other like instances.*

Varieties of alluvial Soil.

"In general," says Sir H. Davy, "the Soils the materials of which are most various and heterogeneous are those called alluvial, or which have been formed by the depositions of rivers; many of them are extremely fertile. I have examined some productive alluvial Soils which have been very different in their composition. A specimen from the banks of the river Parret in Somersetshire, afforded me eight parts of finely-divided matter, and one part of silicious sand; and an analysis of the former gave the following results:

	Parts.
Carbonate of lime	360
Alumina	25
Silica	20
Oxide of iron	8
Vegetable, animal, and saline matter	19

* *Agricultural Chemistry*, p. 184.

"A rich Soil from the neighbourhood of the Avon in the valley of Evesham, in Worcestershire, afforded me three-fifths of fine sand, and two-fifths of impalpable matter. This last consisted of

	Parts.
Alumina	35
Silica	41
Carbonate of lime	14
Oxide of iron	3
Vegetable, animal, and saline matter	7

"A specimen of good Soil from Teviotdale afforded five-sixths of fine silicious sand, and one-sixth of impalpable matter; which consisted of

	Parts.
Alumina	41
Silica	42
Carbonate of lime	4
Oxide of iron	5
Vegetable, animal, and saline matter	8

"A Soil yielding excellent pasture from the valley of the Avon near Salisbury, afforded one-eleventh of coarse silicious sand; and the finely-divided matter consisted of

	Parts.
Alumina	7
Silica	14
Carbonate of lime	63
Oxide of iron	2
Vegetable, animal, and saline matter	14"*

Knowledge of Soils furnishes useful correctives.

The knowledge acquired by this analytical process of the component parts of Soils, possesses its chief value as it suggests the readiest means for the improvement of bad land, as well as for the successful management of that which is good. In ascertaining the composition of sterile Soils, for instance, any particular ingredient which is the cause of their unproductiveness will probably attract the notice of the Agricultural Chemist; whom in this case, the farmer should employ exactly on the same principle as he calls in the Farrier when his horses are sick, or the Physician when a disease has found its way into his family. If, for example, in analyzing a portion of barren Soil, it be found to contain the salt of iron, or any other acid matter, it may be ameliorated by the application of quick-lime. A Soil of an apparently good texture was put into the hands of Sir H. Davy, as remarkable for sterility. On examining it he found that it contained sulphate of iron, and accordingly recommended the obvious remedy of top-dressing with lime, which converted the sulphate into a manure. If there be an excess of calcareous matter in the Soil, it may be improved by the application of sand or clay. Soils, again, too abundant in sand are benefited by the use of clay or marl or vegetable matter. Peat as a top-dressing has been found to answer well for correcting the defects of a light sandy Soil; while a deficiency of vegetable or animal matter must be supplied by the richest species of manures. An excess of vegetable matter, on the other hand, is to be removed by burning, or to be remedied by the application of earthy materials. The improvement of peats, or bogs, or marsh lands must be preceded by draining; stagnant water being injurious to all the nutritive classes of plants. Soft black peats when drained, are often made productive by the mere application of sand or clay as a top-dressing. When peats are acid, or contain ferruginous salts, calcareous matter is absolutely necessary in bringing them into cultivation.

* *Agricultural Chemistry*, p. 186.

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When they abound in the branches and roots of trees, or when their surface entirely consists of living vegetables, these must either be removed or destroyed by burning. In the latter case, their ashes afford earthy ingredients fitted to improve the texture of the Soil on which they were formerly an incumbrance. In a word, the best natural Soils are those of which the materials have been derived from different strata of rocks; which have been most minutely divided by air and water, and are intimately blended together; and in improving Soils artificially the farmer cannot do better than imitate the processes of Nature. The materials necessary for the purpose are seldom far distant; coarse sand is often found immediately on chalk; and beds of sand and gravel are common below clay. The labour of improving the texture and constitution of the Soil is repaid by a great permanent advantage, for its fertility is thereby placed on a lasting basis; and while the annual outlay is lessened the yearly produce is increased.

Modes of examining Soils.

In whatever way a Soil is to be examined, specimens of it should be taken from different parts of the field, and a few inches below the surface; and it should be carefully ascertained whether these portions so selected possess similar properties. On extensive plains the whole of the Soil is found to be rather uniform in the nature and proportion of the ingredients of which it is composed; but in valleys and near the beds of rivers which are supplied with the materials of the Soil from the higher grounds, there is necessarily a greater variety. One part of the field presents a calcareous Soil, and another a silicious. The specific gravity in all cases is an indication of the quantity of organized matter which it contains; for such matter is most abundant in lighter Soils. To ascertain the specific gravity of any given layer of earth, an equal bulk of it and of water may be introduced into a phial of a determinate capacity. If a bottle containing four hundred grains of water be half-filled with that liquid, and if the remaining half be filled with the Soil to be examined, and if the bottle gain two hundred grains of weight more than when it is entirely filled with water, the specific gravity of the Soil is double that of the water. The colour, feel, and some other Physical properties of Soils may, to a certain extent, lead to a knowledge of their composition. For example, a silicious Soil is rough and hard to the touch, and when rubbed on glass scratches it. A red or yellow colour denotes a ferruginous Soil, while softness in general denotes one that is calcareous.

Influence of temperature.

The power of absorbing and retaining heat and moisture seems to be closely connected with fertility of Soil. Certain Soils are more easily heated than others, and when brought to the same degree of temperature, cool more rapidly. Stiff white clay is heated with difficulty, and from the quantity of moisture which it embodies, retains the heat but for a short time. A chalky Soil also is heated with difficulty, but retaining less moisture the warmth is not so soon expelled. A black Soil in which soft vegetable matter predominates is most freely heated by the sun and air. Deeply coloured Soils, and such as possess a large proportion of carbonaceous and ferruginous matter, acquire, when exposed to the sun, a higher temperature than Soils of a paler complexion. A rich black mould, containing nearly a fourth part of vegetable matter, when under the influence of sunshine, had its temperature raised in the space of an hour from 65° to 88° of Fahrenheit; while a chalky soil under a similar influence rose only to 69°. The mould being removed into the shade where the temperature was 62°, lost in half an hour 15°; whereas the chalk Soil in the same situation sank only 4°. A cold, fertile Soil and a cold, barren clay, being previously dried, were heated to the temperature of 88°, and afterwards exposed to the air in a place in which the thermometer stood at 57°; in half an hour the former lost 9°, while the other was deprived of no more than 6°. An equal portion of the clay containing moisture was heated to 88°, and then exposed to a temperature of 55°; in a quarter of an hour its heat became equal to that of the room. In conducting these experiments, which were made by Sir H. Davy, the Soils were placed in small tin-plate trays, two inches square and half an inch in depth.*

Of absorption.

The temperature of the Soil, or its power of combining with and retaining heat, is in all cases greatly modified by the property it possesses of absorbing moisture; and this latter quality depends in a great measure on the degree of comminution to which its parts are reduced; for the more they are divided the more active is their power of absorbency. This property is greater in vegetable than in animal substances; and these last possess it in a higher degree than compounds of the earths, and a considerable diversity prevails in the different proportions of the earths themselves. It has been already suggested that the fertility of a Soil has a close connection with its power of drawing moisture from the atmosphere. Experiments to ascertain the extent of this property can be easily made, and a very simple method of determining the relative productiveness of land is obtained by them. "I have," says Sir H. Davy, "compared the absorbent powers of many Soils with respect to atmospheric moisture, and I have always found it greatest in the most fertile Soils. A thousand parts of a celebrated Soil from Ormiston, in East Lothian, which contained more than half its weight of finely divided matter, of which 11 parts were carbonate of lime, and 9 parts vegetable matter, when dried at 212°, gained in an hour, by exposure to air saturated with moisture at temperature 62°, 18 grains.

"1000 parts of a very fertile Soil from the banks of the river Parret in Somersetshire, under the same circumstances, gained 16 grains.

"1000 parts of a Soil from Mersey, in Essex, worth 45*s.* an acre, gained 13 grains.

"1000 grains of a fine sand from Essex, worth 28*s.* an acre, gained 11 grains.

"1000 of a coarse sand, worth 15*s.* an acre, gained only 8 grains.

"1000 of the soil of Bagshot-heath gained only 3 grains."

Water and the decomposing animal and vegetable matter existing in the Soil, constitute the true nourishment of plants; and as the earthy parts of the Soil are useful in retaining water so as to supply it in the proper proportions to the roots, so they are likewise efficacious in producing the proper distribution of the animal and vegetable matter to the expanding fibres of the organized bodies, or plants, which go in search of it, as their natural sustenance.

Soils which repose immediately upon a stratum of rock become much sooner dry by the process of evaporation than when the subsoil is of clay or marl. The contiguity of the strata to the superincumbent layer of earth is supposed to be one of the principal causes of

* *Agricultural Chemistry*, p. 141, &c.

Agriculture. the remarkable fertility of the land in the humid climate of Ireland. A subsoil in which clay predominates is sometimes extremely beneficial to a sandy field in aiding its deficient absorbent power, and supplying the moisture which is lost by the action of the atmosphere and the process of vegetation; while, on the other hand, the excessive degree of absorbent power in a Soil is often corrected by a subsoil of a sandy or gravelly nature. In calcareous Countries, where the surface appears to be a species of marl, the limestone is only a few inches from the Soil; but the contiguity of the rock impairs not its fertility, although a less absorbent Soil in such circumstances would be rendered sterile. This is finely exemplified in the appearance of the sandstone and limestone hills in Derbyshire and North Wales during the summer season; the grass of the former usually exhibits a brown and parched aspect, while the latter are clothed with a rich and beautifully verdant covering.

Leaving all the considerations which respect the improvement of land until we come to the subject of manures, we shall now proceed to the theory and practice of draining; following herein what we consider the natural order of events in the improvement and culture of land. It is obvious, indeed, that to whatever purpose the Soil is destined, whether pasture or tillage, it is necessary that it should in the first instance be relieved from superfluous moisture. Even the temporary stagnation of water on arable land may interrupt the usual operations of the husbandman at the most important season of the year, while it can hardly fail to counteract his labours in weeding and manuring, and, in the end, blast all his hopes of a remunerating crop. The produce of grass-lands, too, in which water is redundant, is always coarse and deficient in nutriment; and hence every intelligent farmer directs his first cares to the draining of his fields.

Of Draining.

Geological Principles. The successful practice of Draining depends in a great measure on a proper knowledge of the Geological structure of the Earth's surface, or of the various strata of which the outer crust, so to speak, is composed, as well as of their relative degrees of porosity, or capability of admitting the passage of water through them, and likewise of the manner in which water is collected in the higher grounds and conducted to those of a lower level. In whatever way the elevations which present themselves on the surface of the Globe were originally formed, it has been clearly shown, by sinking large pits, or by opening quarries in the sides of hills, that they are for the most part composed of beds having an oblique or slanting direction downwards. Some of these strata, from their peculiar properties, allow water to percolate freely through them; while others, so far from admitting a passage, force it along their surfaces without penetrating them in any degree, and thereby compel it to seek an outlet in the grounds below. There, in general, it is obstructed or dammed up, by meeting with impervious materials of some kind or other, by means of which it is raised into the superincumbent layers, if they happen to be open or porous, soon rendering them too wet for the purposes of Agriculture: but where they are of a more tenacious and impenetrable quality, they only become gradually softened by the stagnant water below them; by which, however, the surface of the ground is rendered equally moist and swampy, though somewhat more slowly than in the former case. It may also be observed that some of the strata which constitute such hilly or mountainous tracts are found to be continued with much greater regularity than others; those which are placed nearest to the surface, at the inferior parts of such elevations, being mostly broken or interrupted before they reach the higher parts of them; while those which lie deeper or below them at the bottom, show themselves near the summit. Thus, that stratum which may lie the third or fourth, or still deeper, at the commencement of the valley, may form the uppermost layer at the top of the hill; an arrangement which may have been produced partly by the circumstances attending the original elevation of such mountainous regions, and partly by the fact that the materials of the exterior strata, being dissolved by the action of the atmosphere, by successive frosts and rains, have been carried down into the valleys, and thus left such as were immediately below them in an exposed condition.*

Effects of different strata. These elevated strata frequently prove the means of rendering the lower grounds wet and swampy; for the general moisture of the atmosphere being condensed in much greater quantities in such elevated situations, the water thus formed, as well as that which falls in rain and sinks through the surface, insinuates itself and thus passes along among the inferior strata which compose the sides of such elevations, until its descent is retarded by some impenetrable substance, such as clay or a very compact rock. It is there collected in a body, and ultimately forced to filtrate slowly over it, or to rise to the light, and to constitute, according to the different circumstances of the case, swamps or marshes in the contiguous valleys. The appearances are more commonly oozing springs, weeping rocks, or sometimes a considerable rivulet formed by the union of small currents under the ground. This is obvious from the sudden disappearance of moisture in some parts of lands, while it stagnates, or remains till removed by the effect of evaporation, on others; as well as from the force of springs being stronger in wet than in dry weather, breaking out frequently after the land has been impregnated with much moisture in higher situations, and as the season becomes drier, ceasing to flow except at the lower outlets. The force of springs, or proportion of water which they send forth, depends likewise in a great measure on the extent of the high ground on which the moisture is received and detained, furnishing extensive reservoirs or collections of water by which they become more amply and regularly supplied. On this account what are termed bog-springs, or such as rise in valleys and low grounds, are considerably stronger and more regular in their discharge, than such as burst forth on the more elevated situations or sides of eminences.†

Modes of ascertain the of moisture. In Draining land the first thing to be considered is the source of the wetness; whether it be surface-water which from some obstruction is not permitted to pass off freely, or whether it be thrown up, as has just been described, from some of the inferior strata. If a hollow piece of ground be covered with water, or if it should be only wet and spongy during great part of the year and even during the dry season; and, when this ground has been for some time retained in pasture, if the common rush begin to shoot up and thrive on the edges of the wet spot where the soil is somewhat more solid, and if it stretch upwards on the sides of the declivity, and more

* Darwin, *Phytologia*, p. 258. London, p. 691.
† Elkington, *Mode of Draining*, p. 15.

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particularly to a greater height on one side—then the conclusion is pretty certain that the water proceeds from the underground strata, from a bed of gravel or other porous matter, at some depth under the surface, and supported by an impervious bed, such as a mass or layer of clay. If a pit be dug at the upper edge of the place occupied by the rushes, to the depth of two or three feet —which must vary according to the thickness of the different strata and the depth of the porous bed through which the water filtrates—as soon as the latter stratum is penetrated the water will rise in the pit, and perhaps in a short time overflow and run along the surface. But if a cut, of sufficient dimensions to convey the whole of the water to the nearest ditch, be made, it is probable the wet ground will be relieved from the water, the rushes will disappear, and plants of a very different character take their place. In case no water should appear in the pit, after digging to a moderate depth, or if it should not be convenient to penetrate deeper than a foot and a half or two feet, recourse may be had to the borer or auger; an instrument employed for the purpose of forming a communication with the porous stratum which contains the water, to the depth of many feet or fathoms. When the borer reaches the porous stratum and is withdrawn, the water will be seen to burst up with considerable force and soon fill the pit; and if the communication thus formed continues uninterrupted, the ground becomes dry, and is quickly rendered fit for all the purposes of tillage.

Mr Elkington's discovery.

To Mr. Elkington is usually attributed the merit of having invented this process of Draining, the origin of which is explained by Mr. Johnstone, the author of the *Account of the most approved System of Draining Land.* "In the year 1763, Mr. Elkington was left by his father the possession of a farm called Princethorp, in the parish of Stritton-upon-Dunsmore, and County of Warwick. The soil of this farm was very poor, and in many places so extremely wet that it had been the cause of rotting several hundred sheep, which was the first means which determined him if possible to Drain it, which he began to do in 1764. The field in which he began was of a wet clay soil, rendered almost a swamp (and indeed in some places a *shaking-bog*) by the springs issuing from a bank of gravel and sand adjoining it, and overflowing the surface of the clay. In order to Drain this field, he cut a trench about four or five feet deep a little below the upper side of the bog, or where the wetness began to make its appearance; and after proceeding so far in this direction and at this depth, he found that it did not reach the *main body of subjacent water* from whence the evil proceeded. On observing this Mr. Elkington was at a loss how to proceed. At this time while he was considering what was next to be done, one of his servants accidentally came to the field where the Drain was making, with an iron crow or bar, which the farmers in that country use in making holes for fixing their sheep hurdles. Mr. Elkington having a suspicion that his Drain was not deep enough, and a desire to know what kind of strata lay under the bottom of it, took the iron bar from the servant, and after having forced it down about four feet below the bottom of the trench, on pulling it out, to his astonishment, a great quantity of water burst up through the hole he had thus made, and ran down the Drain. This at once led him to the knowledge of wetness being often produced by water confined further below the surface of the ground than it was possible for the usual depth of Drains to reach, and induced him to think of applying an auger as a proper instrument in such cases. Thus did the discovery originate from chance, the parent of so many useful Arts! In this manner he not only accomplished the Drainage of this field, which soon rendered it completely sound, but likewise all the other wet ground on his farm."*

His three rules.

The success of this experiment soon extended Mr. Elkington's fame, as a Drainer, throughout the whole Kingdom. From long practice on grounds of every variety of character and situation, he acquired a great facility in judging relative to the nature of the concealed strata and the sources of the hidden springs. The rules on which he acted may be reduced to three: first, finding out the *main spring* or cause of the evil, without which nothing effectual could be done; second, taking the level of that spring, and ascertaining *its subterraneous bearings*, a measure never practised by any till Mr. Elkington explained the advantages to be derived from it; for if the Drain be cut a yard beyond *the line of the spring* you can never reach the water that issues from it, whereas by ascertaining that line, by means of levelling, you can cut off the spring effectually, and consequently Drain the land in the cheapest and most complete manner. And third, making use of the auger to reach or *tap* the spring, where the depth of the Drain is not sufficient for that purpose.

Their application

In proceeding according to this method of Draining, the neighbouring high grounds are to be examined, to ascertain precisely the nature, composition, and inclination of the strata, and their relative position with the land to be improved; from which an opinion can be formed of the nearest point at which the water may be cut off and discharged by the level of the spring. To obtain this necessary information, the beds of the nearest streams, the face of steep banks, pits, wells, and quarries are to be nicely surveyed. Having discovered the main spring, the next object is to determine accurately the line of level in which the Drain is to be conducted. This is one of the most important parts of the operation, and requires particular attention. The last part of the operation is the application of the auger, which is employed in all cases where the outlet, or the expense or the difficulty of execution does not admit the Drain to be cut so deep as to reach the spring.

illustrated.

The Principles now explained will not, we think, be found difficult in application when all the circumstances are fully considered. Suppose there is an extensive flat of swampy land, lying on the bank of a river, and from an examination of the appearances it is concluded that the water is collected from numerous springs, indications of which are distinctly observed on the declivity of the adjoining bank which forms the boundary of the bog on one side; and suppose at the same time that all the springs arise along the upper edge of the wet ground, then, it is very probable, that a single drain conducted in the direction of these springs will effectually carry off the redundant water. But let it be supposed further, that on examining the surface from which the springs issue, they appear at different levels; that the upper series of springs is exhausted in the dry season, while those in the lower part of the declivity continue to flow; the conclusion in this case is pretty evident, that the whole springs are derived from the same source. The lowest are to be considered as the chief springs, and the line of the Drain accordingly is to be carried in their

* Elkington, *Mode of Dr[illegible]* p. 6.

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direction, by which the run of water is completely intercepted. If the Drain were carried in the direction of the upper line of springs, it would also answer the purpose, but it would require deeper cutting, and therefore a greater expense would be incurred; or the use of the auger might be required, which by the first method would be entirely superseded. It is scarcely necessary to add that extensive bogs or swamps may require subsidiary trenches in different places to carry off the whole of the water.

Indications from the soil.

The irregular distribution of the strata of which hills are composed, frequently produces alternate portions of wet and dry ground on the surface. The general aspect of the soil, the nature of the plants, and the degree of wetness which prevails, may, in many cases, indicate the arrangement of the rocky beds, and hence the proper direction of the intended Drain. When the stratum is horizontal or only slightly inclined, all the springs may derive their water from the same source, and when this is exhausted the object will be attained. But in cases where the rock is nearly in a vertical position, and contains partial collections of water in fissures and cavities, it is necessary to carry a Drain to each outlet.*

"In many hills composed of alternate strata of rock, sand, and clay, the surface of the latter is commonly wet and swampy, while that of the former is dry and productive, and therefore requires as many cuts to Drain it completely as there are divisions of wet and dry soil. The highest parts of the hill being for the most part composed of porous soil, receive the rain-water which descends through it till it meet some impervious stratum, as clay, which obstructing its percolation any further downwards, it then rises to the surface and forces itself a passage over that impassable stratum. After it has thus overflowed the *upper clay* surface, it is immediately absorbed by the next porous stratum, and descending into it in like manner as above, it again issues at the lower side of it, and injures the surface of the next clay bed as it did that of the first. In this manner, the same stream will affect the other similar strata of which the hill is composed, down the whole declivity, and form at last in the hollow a lake or bog, if there is not a proper outlet or descent to carry off the water. To Drain a hill side of this description, it is necessary to begin by making a trench along the upper side of the *uppermost* rushy soil, which will have the effect of cutting off the highest spring; but as the rain falling on the next porous soil subsides to the lowest part of it and forms another spring, a second cut is necessary there to prevent that water from injuring the surface of the next clay bed. Thus, similar cuts will be requisite down the descent so far as the same springs and appearances continue to injure the ground.† See fig. 4, 5, and 6.

The Draining Borer.

The borer used in Draining is nearly similar to that made use of in searching for coal or other subterraneous minerals. The auger, shell, or wimble, as it is variously called, for excavating the earth or strata through which it passes, is from two and a half to three and a half inches in diameter; the hollow part of it one foot four inches in length, and constructed nearly in the shape of the wimble used by carpenters. The rods are made in separate pieces, of four feet long each, which screw into one another to any assignable length which the depth of the hole requires.

* Elkington, *Mode of Draining*, p. 19. &c.

† *Ibid.* p. 43.

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Mode of using it.

To judge when to make use of the borer is a difficult part of the business. Some who have not seen it made use of in Draining have been led into a mistaken notion, both as to the manner of using it, and the purpose for which it is applied. They think that if by boring indiscriminately through the ground to be Drained, water is found near enough the surface to be reached by the Drain, the proper direction for it is along these holes in which water has been found; and thus they make it the first implement that is used. But a process directly opposite ought to be followed, and the auger should never be used until after the Drain is cut; and then it should be employed for the purpose of perforating a retentive or impervious stratum, lying between the bottom of the Drain and the reservoir or strata containing the spring. The manner of using it is simply thus: two men above, one on each side of the Drain, turn it round by means of the wooden handle; and when the auger is full they draw it out, and a man in the bottom of the trench clears out the earth, assists in pulling it out and directing it into the hole, and also gives occasional aid in turning with the iron handle or key, when the depth and length of rods require additional force to perform the operation. In one word, the auger may be described as bearing the same relation to dropsical land that the tapping instrument in the hand of a surgeon does to a human patient labouring under *anasarca;* and in both cases the success of the operator is in proportion to his theoretical knowledge of the subject, and the extent of his actual practice.*

The invention disputed.

The honour of this discovery, although usually conferred upon Elkington, has not been undisputed. In Dr. Nugent's *Travels through Germany*, printed in the year 1768, there is an account of a mode of Draining land on principles in some respects of a similar nature, not indeed by the use of the auger but by making pits. And in a publication by Dr. James Anderson, entitled *Essays on Agriculture and Rural Affairs*, and bearing date 1775, the author, after describing a mode of tapping by sinking small pits, adds, "I have often imagined that the expense of digging these pits might be saved by boring a hole through this solid stratum of clay, with a wimble made on purpose; but as I have never experienced this, I cannot say whether it would answer the desired end exactly." There seems to be no doubt, however, that Mr. Elkington made use of the auger, prior to the date of either of these publications, or to any hint he could possibly derive from any Work in the English Language, though it is probable that as regards boring the ground for wells, the use of the said instrument was long known in various Countries, especially in Italy. It is proper to observe, at the same time, that although Dr. Anderson's Essays were not published till 1775, the experiments which he describes were made in 1761, and moreover that the account of Mr. Elkington's operations

* A correspondent of the *Quarterly Journal of Agriculture* writes as follows: "Boring with augers and digging wells formed the peculiar features of Elkington's mode of Draining, joined to that of deep cutting; but, the latter part only of his mode has been carefully preserved and practised, while the former part has been too much neglected. In one instance of my own in Draining, of which I have had considerable experience, the digging of a well about eight feet deep saved the expense of making a Drain two hundred yards long. Had the well not been attempted at all, that length of Drain must have been cut along a fall of only twenty inches. The well terminated in a thick bed of gravel, which easily absorbed all the water that could possibly have passed through all the Drains connected with it." No. XIII. p. 82.

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was not committed to the Press till the year 1796. The decision of Parliament, which granted to the latter a reward of £1000, settled the question in a very important point; leaving nothing but empty honour as the subject of controversy.*

Surface Draining.

As *surface Draining*, the second department of this branch of husbandry, is conducted on the very obvious principle of having ditches on the lower sides of a field, into which the furrows discharge the superfluous moisture not absorbed by the soil, there will not be occasion for any lengthened remarks. In extensive flats, however, which are covered with water a great part of the year, a more expensive operation becomes necessary. A main Drain, conducted from the intended outlet, must be formed with such a slope and of such a depth as shall be sufficient to relieve the land from so injurious an incumbrance. The course of a Drain of this description, when the inclination of the ground is not perceptible, is formed by the ordinary process of levelling, and in most cases by the use of the spirit-level alone. But without any instrument, those who are familiar with practical Draining can discover the declivity and the course of the water even in land which appears nearly flat, by examining the ditches when they are almost dry in Summer, and by observing to what point the leaves of aquatic plants are directed. When the extent of ground to be freed from water is considerable, a single Drain ought not to be held sufficient. In this case branches from different parts of the field uniting with the main Drain are absolutely necessary; and the number and direction of these branches must be determined by the extent and inequalities of the surface. The subordinate Drains or branches should form a junction with the main Drain in the direction of the current, to avoid the danger of sand or earth accumulating and creating obstructions when they enter it transversely.

Shape of Drains.

We need scarcely observe that the declivity of the ground in many cases must regulate the slope of Drains; but where the outlet and other circumstances afford an opportunity for marking its limits, it should neither, on the one hand, be too great, in which case the sides and bottom exposed to the rapidity of the current might be apt to receive injury; nor, on the other hand, should the inclination of the Drain be too small, by which the current becomes sluggish and stagnant, and the land is not fully relieved from water. A similar discretion must be exercised in the dimensions of open Drains, as such are necessarily varied according to the nature of the soil, the situation, and the quantity of water to be carried off. The width at the bottom of the Drain must be regulated by the proportion of water to be discharged; and it may be stated as a general rule, that the width at top should be at least three times greater, to admit of sufficient slope and solidity to the sides. But in soft and mossy soils even a larger slope is requisite; and wherever the Drain is not meant for a fence as well as a channel for conveying water, the earthy matters thrown out should not be left on the sides to form an elevated bank, but spread on the field or altogether removed. In marshy grounds where the Drain is also required to be a fence, the soil, which should always be thrown out on the lower side, should be allowed to remain; and a small parallel cut may be opened to receive the surface-water from that side, and to conduct it to a convenient place where it may be admitted into the larger Drain.

Open Drains.

In all cases where there is much risk of surface-water being greatly increased in the time of rain, open Drains should always be preferred, to avoid the danger of being entirely obstructed, a casualty to which covered Drains are very liable. But as such Drains, constructed in the usual way, would disfigure an improved field and interrupt the accustomed operations of tillage, they ought to have a greater slope, and a greensward should be permitted to form on their sides. If the direction of the ridges be parallel to the Drain the cultivation of the field is uninterrupted; and when it is in pasture, it presents no obstacle to the free passage of cattle. But the farmer should remember that whatever may be the slope of such Drains, the sides should never be ploughed; for any increased flow of water in that event would carry off the loosened soil.

Hollow Drains in pastures.

When smooth pasture-ground is subject to the collection of surface-water, the evil may be remedied by means of a simple operation with a common plough. Let a deep furrow be turned up through the hollow parts of the field where water stagnates, pare off the earth from the inverted sod, leaving it about three inches thick, and return it to its natural position. In this way a small hollow Drain of three or four inches is left in the bottom of the furrow, which is found sufficient to discharge a considerable quantity of water. By this easy process a great extent of Drain can be executed in a short time; and when any part is obstructed, it can be repaired at a small expense. Lands, again, which are appropriated to woods or plantations, are equally benefited by Draining as those devoted to the production of corn crops, or to the feeding of cattle. For such grounds, open Drains are by far the most suitable; for in covered Drains the roots of the trees, stretching along horizontally, insinuate themselves among the stones, interrupt at first, and finally obstruct the progress of the water.

Drains in a flat soil with clayey subsoil.

The skill of the Drainer is frequently put to the test when he is called upon to remove the superfluous moisture from land which is at once flat and possesses a very retentive or clayey soil. The upper layer of earth being porous readily permits the rain to sink through it while the impervious subsoil prevents it from descending further, and hence the ridges are usually saturated with an excess of water. Land thus circumstanced is described by farmers as being *wet-bottomed*. When the field to be Drained has only a slight declination or slope from the sides towards the middle, one Drain cut through the porous superficial materials into the clay in the lowest part of the ground may be sufficient to bring off the whole of the water detained in the porous soil. This effect may likewise be greatly promoted by laying out and forming the ridges so as to accord with the direction of the land, and by the use of the plough or spade in removing obstructions and deepening the furrows. In such situations, where the Drain has been formed in this manner, the water will flow into it through the porous surface-materials as well as if a number of small trenches were cut from it to each side, as is the practice in Essex and some other parts of the country; but which is often an unnecessary labour and expense. The Drain made in the hollow may frequently serve as a division of the field, in which case it may be open, but in other

* See Elkington, *Mode of Draining*, p. 10, where the following notice is inserted. "Buffon states that, in the city of Modena and for miles round, whatever part is dug, when we reach the depth of sixty-three feet, and bore five feet deeper with an auger, the water springs out with such force that the well is filled in a very short space of time. The water flows continually, and neither diminishes nor increases by the rain or drought."

Agriculture. circumstances it may be more proper to have it covered.

When a field of this description has more than one hollow in its surface, it will obviously be requisite to have more than one main Drain; but when it is nearly level or only inclined slightly to one side, a trench or Drain along the lowest part, and the ridges and furrows formed accordingly, may be sufficient for effecting its Drainage. There may, however, be cases, as where a field is large and very flat, in which some side cuts in the principal Drain may be necessary, which must be dug a little into the clay, and as narrow as they can be wrought, and then filled up with stones or other suitable materials. What is called the Essex method of Draining in ploughed, springy lands, where the surface soil is tenacious, is described by Kent, and consists in substituting small under Drains for open furrows; or in some cases having a small under Drain beneath every second or every third furrow. These Drains lead to side or fence ditches where they discharge themselves.

Draining a clayey surface.

Where the clay constitutes the surface and the porous body is underneath,* the injurious stagnant water cannot possibly get off without the assistance of Drains formed for the purpose. Soils of this nature are Drained with difficulty and require a much greater number of trenches or cuts than those of any other kind, as they must be marked out and disposed in such a way as to collect and convey the water every where from the surface; because it can only force itself off into them from above, being prevented from sinking in through the clay as in soils of a contrary kind. Where there happen to be hollows or irregularities in the surface of the land, water may often be observed to continue standing in them at a distance of but a few feet from the Drain. In Draining such lands it will always be necessary in the first place to make a large or conducting Drain at the lowest part, or the end of the field, for the purpose of receiving and conveying away the water collected by the smaller collateral cuts which it may be necessary to make on each side of it. Where it suits for the purpose of dividing the land, this principal Drain may be better open than covered, as by that means the mouths or outlets of the different small Drains that come into it may be conveniently examined, and cleared out when necessary.

Construction of ridges.

The construction of the ridges in such soils so that they may accord with the declivity is a matter which must be carefully kept in view. They should in all such cases have a degree of elevation or roundness in the middle, sufficient to afford the water a ready fall into the furrows, which likewise should have such a depth and fall, as may take it quickly into the Drains. The ridges, being well laid up, should have small open Drains formed in a slanting direction across them in such a manner as to form communications with one another and with the furrows; by which means they are made to perform the office of Drains; the water coming upon the ridges being thus readily conveyed into the furrows along which it proceeds, till impeded in its course by the ground or other cause; it then passes through the open cross Drains into others where the descent is greater, and ultimately into the ditch or other passage at the bottom of the enclosure. The elevation of the ridges should probably, too, be made greater for the Winter than the Summer crops, as there must be much more injurious moisture at the former than the latter season.*

* Loudon, p. 704. Marshal *on Landed Property*, and Dr. Anderson's *Treatise on Draining*.

This may be easily accomplished at the time of ploughing the land. Agriculture.

Of the different kinds of Drains used by Agriculturists we may mention those which are formed of stone, brick, gravel, cinders, wood, spray, straw, turf, and tile. See fig. 7 to 13.

Rubble Drain.

The first of these, or the common *rubble* Drain, is formed of rough land-stones of any sort, broken so as not to exceed two or three inches in diameter. No good drainer uses stones six or eight inches in diameter in any part of a rubble Drain, least of all at the bottom. The point kept in view is to use such small stones at the bottom as may allow the water a great many channels; so that if a few should become impermeable, there should be many others remaining. The nearer the bottom of a Drain of this kind approaches to the character of a natural bed of gravel, the more certain will be the free passage of the water. Gravel or ashes should be laid on the top of the stones, on these a thin layer of straw or haulm of any kind, and the remainder filled up with the surface soil.

Brick Drain.

The *brick* Drain is formed in a great variety of ways, either with common bricks and bats, in imitation of the boxed and rubble, or rubble Draining, or of bricks made on purpose, of which there is great variety.

Gravel Drain.

The *gravel* or cinder Drain is seldom made deep, though if the materials be large they may be made of any size. In general they are used in grass-lands; the section of the Drain being an acute-angled triangle, and the materials being filled in, the smallest uppermost, nearly to the surface of the ground.

Wood Drain.

The *wood* Drain is of various kinds. A very sufficient and durable construction consists of poles or young fir-trees stripped of their branches, and laid in the bottom of the Drain lengthways. They are then covered with the branches and spray. Another form is that of filling the Drain with faggot-wood with some straw over. A variety of this mode is formed by first setting in cross-stakes to prevent the faggots from sinking; but they are of no great use, and often occasion such Drains to fail sooner than common faggot Drains. In some varieties of this Drain, brushwood is first laid down at its side, and formed by willow or other ties into a continuous cable of ten or twelve inches in diameter, and then rolled in; which is said to constitute an excellent Drain with the least quantity of materials, and to last a longer time than any of the modes above mentioned. Some cut the brushwood into lengths of three or four feet, and place them in a sloping direction, with the root end of the branch in the bottom of the Drain. Others throw in the branches at random with little preparation and cover them with spray, straw, or rushes, and finally the surface soil.

Spray Drain.

The *spray* Drain is generally, like the gravel Drain, of small size, and formed like it with an acute-angled bottom. In general the spray is trodden firmly in; though in some cases it is previously formed into a cable, as in the brush-wood Drain. Drains of this sort are much in use in grass-lands, and when the spray of larch wood, heath, or ling can be got, they are of great durability.

Straw Drain.

The *straw* Drain, where reeds, rushes, and bean-straw are used, is sometimes made like the spray Drain, by pressing the loose materials down or forming a cable; but in general the straw is twisted into ropes as big as a man's leg, by the aid of a machine, and three or more of these are laid in the bottom of a triangular Drain, with or without the protection of three turfs; where some sorts

Agriculture. of moss, as *sphagnum* or *lycopodium*, can be got, these Drains are of very great durability.

Turf Drain. The *turf* Drain may be made of any convenient depth, but it must be at least the breadth of a turf at bottom. The Drain being dug out, as if it were to be filled with stones or any ordinary material, the operator next, with a spade three inches wide, digs a narrow channel along its centre, clearing it out with the Draining scoop; and over this the turfs are laid without any other preparation or any thing put over them, but the earth that was excavated. This is found to be very cheap, and, considering the materials, a surprisingly durable method of Draining; answering in pasture-fields especially all the purposes that the farmer can expect to derive from Drains constructed with more labour and at a much greater expense. They are said frequently to last twenty years and upwards; but the period during which they will continue to prove effectual, must depend on the nature of the soil and the current of water.

in Cheshire. A mode of turf Draining used in Cheshire is described as follows: the surface of the ground, in which the Drain is intended to be cut, is marked out in parallelograms about the size of bricks on one side, while the opposite side to the width of nine inches, or that of a common sod, is left unbroken. These sods are taken out at a spade's depth, and laid carefully by the side of the Drain for covers. The other sods, resembling bricks in their size and shape, are then dug, and laid carefully on the same side as the sods intended for covers. The Drain is then sunk to the proper depth, and the stuff taken out is thrown to the other side. The bottom is levelled with proper draught for the water, and set with the sods like bricks, two in height on each side; these are covered with the larger sods set obliquely, the grassy sides being turned downwards.

Wedge Drain. The *wedge* Drain is constructed as follows. When the line of Drain is marked out, a sod is cut in the form of a wedge, the grass side being the narrowest, and the sods being from twelve to eighteen inches in length. The Drain is then cut to the depth required, but is contracted to a very narrow bottom. The sods are then set in with the grass sides downwards, and pressed as far as they will go. As the figure of the Drain does not suffer them to go to the bottom, a cavity is left, which serves as a water-course; and the space above is filled with the earth thrown out. The work is performed by means of three spades of different sizes. The first may be a common spade of moderate breadth with which the surface clay may be taken off to the depth of eight or ten inches, or not quite so much if the clay be very strong. The breadth of the Drain at top may be from a foot to fifteen inches; but it never should be less than a foot, as it is an advantage that the sides should have a considerable slope; and the two sides should slope as equally as possible. Another workman follows the first with a spade six inches broad at the top, and becoming narrower towards the point, at which it should not exceed four inches. The length of the plate of this second spade should be fourteen inches, and with it a depth of a foot or fourteen inches can easily be gained. A third workman, and he should be the most expert, succeeds the second, and his spade should be four inches broad at top, only two inches broad at the point, and fourteen or fifteen inches in length. With this spade a good workman can take out at least fifteen inches of clay. A sort of hoe or scoop, made of a plate of iron, formed nearly into the shape of a half cylinder of two inches diameter, and a foot or fourteen inches long, and fastened at an acute angle of perhaps 70° to a long wooden handle, is now employed to scrape out the bottom of the Drain, and remove any small pieces of clay that may have fallen into it. The grassy side of the turfs being turned undermost, they are put down into the Drain, the workman standing upon them after they are put in, and pressing them down with his whole weight till they are firmly wedged between the sloping sides of the Drain. The ends of the turfs being cut somewhat obliquely, they overlap each other a little; and by this means, although there is a sufficient opening for the surface-water to get down, nothing else can find its way. The open space below the turfs ought to be five or six inches in depth, three inches wide at top, and an inch and a half or two inches at bottom.* The author of the above communication remarks, that wherever sufficient attention has been paid to keep the ditches at the ends of the field clear, so as not to choke up the mouths of the Drains, (a point of great consequence,) they appear to have succeeded very well, and he feels confident that wherever the soil is filled for the purpose, the work properly executed, the Drains of a sufficient depth, and no improper treatment or neglect on the part of the farmer, these Drains will answer the most sanguine expectations. He thinks that they should never be less than three feet deep, otherwise they are apt to give way, either from moles getting down into them in very dry weather, or from the feet of the horses employed in ploughing, when the ground is wet, sinking so far as to injure the turf.

Earth Drain. The *earth* Drain, called also the *clay-pipe* Drain, is better calculated for the purpose of conveyed water already collected than for drying the soil. A Drain is dug to the necessary depth, narrow at bottom, in which is laid a smooth tree or a cylindrical piece of wood, ten or twelve feet long, six inches in diameter at the one end and five at the other, having a ring fastened in the thickest end. After strewing a little sand upon the upper side of the tree, the clay or toughest part of the contents of the trench is first thrown in upon it, and then the remainder, which is firmly trodden down. By means of the ring and a rope through it, the tree is drawn out to within a foot or two of the small or hinder end, and the same operation repeated. A gentleman who has tried this experiment says, that this clay-pipe has conducted a small rill of water a considerable way under ground, for more than twenty years, without any sign of failing. Pipe Drains of turf are sometimes formed where the surface soil is a strong clay, as it is only turfs from such a surface that are sufficiently durable. A semicylindrical spade is used to dig the turfs, and hence the turfs themselves resemble a hollow cylinder divided in two. The Drains being dug to the proper depth, one turf is laid in the bottom of it, and another being placed over, completes the pipe or conduit. The same sort of pipe Drain has been formed out of solid beds of clay, and has also served for a time to convey water.

Tile Drain. The *tile* Drain is used in flat, clayey soils where stones are scarce, and where the declivity is small. The tile fabricated for this purpose is much more concave than that used for roofing houses, resembling, indeed, the form of a sugar-loaf or obtuse cone; and the price, according to the size, varies from twenty-four shillings

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* *Transactions of Highland Society*, vol. vi. p. 568.

to £3 the thousand. In laying out the line of Drains, where it is intended to cut off springs, the usual system is followed. Where the removal of surface-water is the object in view, the natural inequalities, or indentations on the face of the field, are carefully examined, so as to attain the end with as few Drains and with as much effect as possible. Where very stiff clay exists, a Drain even in every furrow, or division of ridges, has been resorted to with much success, and the expense is not so great as might appear at first sight. In other cases, where the soil is of a damp, retentive nature, where the surface is flat and incumbent on a stiff clay, in which there are no springs, main Drains may be run in the lowest parts of the land to be dried, and smaller Drains connected with these, running parallel to each other at stated distances. This mode, when properly executed, answers the purpose in view remarkably well.

Tile Draining at Netherby.

In the *Transactions of the Highland Society* there is an account given of this mode of Draining as practised on the estate of Netherby in Cumberland. The deepness has always been suited to the object in view; Drains for springs in many cases have been very deep, so as to cut through the substratum containing the water, whether that has been gravel or sand; surface Drainage for two feet and a half to four feet and a half deep. In all cases the Drains are cut as narrow as a man can conveniently work in them, decreasing in width as they approach the bottom. The tools used are the common spade, shovel, and pick, or the round-mouthed spades used in forming canals, which in Cumberland are known by the name of navigation spades. The Drains being cut to the required depth, with all the top-soil laid on one side, and all the subsoil thrown out on the other, a narrow-mouthed spade, technically called a spit, corresponding to the breadth of the tile to be used, is then introduced; and with this instrument a bed for the course of the tile is neatly and carefully excavated, the strictest attention being paid to preserve a fair equality in the bottom, and a regular descent for the water; while a frequent use of the spirit-level is most commonly indispensable. But the mode of procedure will be distinctly comprehended by referring to fig. 14.

"A, the Drain cut to any required depth. B, the space for the Draining-tile. C, a bit of slate or broken tile, on which the tiles rest at their joinings; a precaution which may be omitted where the bottom is a very stiff clay. D, a clean-cut, green turf, the grass side next the tile, and clapped carefully over it, to prevent the tile from receiving any damage. E, E, the surface soil, cut out of the top of the Drain, and put above the turf. The remainder of the Drain is filled up, if wished, by the subsoil excavated, or what is more general, this soil is spread on the adjoining ridges, and the sides of the Drain are then sloped in by the spade. Straw, furze, or small brushwood, are sometimes placed next the tiles, but a clean good turf is preferable. It has in some few cases been the practice at Netherby, when the Drains happened to be very near the river, and carriage of course not expensive, immediately after the tiles were placed, to fill up the Drain with the clean blue stones from the bed of the Esk, which are here very small, to as great a depth as was thought necessary, and then to finish off the Drain in the usual way of closing stone Drains. This probably makes the best of all Drains; but with tiles alone the result has been most gratifying on all the varieties of soil mentioned, where the Drains are carefully executed. It has been customary here to use the auger where the tapping of springs was thought necessary."*

Expense.

Expense of Draining by three-inch tiles.

	Per rood of 21 feet.	
Cutting the Drain, say on average 2 feet 9 inches deep, laying the tiles on slate or refuse tile, cutting and laying a turf over the tile, reversing the surface-soil, and covering in	0*s.*	4*d.*
Tiles. 21 to the rood, say at the price paid at Netherby for three-inch tiles, 24*s.* per thousand	0	6¼
Carriage of tiles, average distance three miles, three loads a day, a cart carrying 250, and at 5*s.* per day for horse and cart	0	1¾
Refuse slate, broken tile, and carriage..............	0	0½
Per rood	1	0½

Calculating in the same way, it is found that the expense of Draining by four-inch tiles amounts to one shilling and three-pence halfpenny the rood of twenty-one feet; and that a similar process with tiles six inches in the span will cost one shilling and five pence farthing per rood; the cutting in these cases being from four feet and a half to five feet in depth. But it is added that the three-inch tiles are decidedly the most useful for ordinary purposes. The four-inch tiles are able to discharge a very considerable quantity of water. The six-inch tiles, unless the spring is very strong, or the Drains of great length, are not so much used as the two last sorts; while eight-inch tiles are seldom or never necessary, unless in very particular situations.

Advantages.

This mode of Draining answers uncommonly well in the clay lands of Essex, where the soil is firm and retentive, and where the superfluous moisture does not issue from below, as in more porous grounds. We ourselves are acquainted with a district on the banks of a large river, where the common method of Draining cannot be rendered available owing to the low level of the fields, which has been much improved in its productive qualities by the use of tile Draining. A small channel is constructed in every furrow, supplied with this artificial conduit, and covered to the depth of fifteen or eighteen inches with earth, so as to protect it from the feet of the horses when engaged in ploughing. If the tile be made of proper clay and well burnt, it is found to last many years; and it is acknowledged by the farmers who have had recourse to this expedient, that their crops are so much benefited by it, that they could afford to repeat the operation every three or four years.

Pearson's pipe Drain.

There is a method of *pipe* Draining which takes its name from Mr. Pearson, and has been described in several publications, more especially in the XLVIIth volume of the *Transactions of the Society of Arts*. The ground is first opened by means of a plough, having what is called a horn share. With four horses, a furrow nine or ten inches deep by ten inches in width is raised or taken out. The horns are then removed, the coulters added, and eight horses attached. This cuts the soil to an additional depth of ten inches, and it is immediately removed with narrow spades, and larger or smaller Draining scoops, as may be required. A second pair of coulters cuts the soil to the intended depth, in which case also the earth is taken out by the scoops. The total depth is now about twenty-six inches, the width at top ten inches, and at bottom about one inch. A slide is then dropped to the bottom of the Drain, commencing at its lowest level so as to work up hill. A windlass is next placed at the full length of the rope

* Highland Society Essays in *Quarterly Journal of Agriculture*, No. 6. p. 395.

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which is attached to the slide. Clay is next rammed firmly down on the slide with a heavy rammer, to the depth of three or four inches, and the slide is next pulled forward, leaving a cylindrical Drain, three or four inches in diameter, according to that of the slide.

Its application.

This is, in effect, the same as that described above under the denomination of the earth or clay pipe Drain; the mode of forming the excavation and the conduit being alone different. It is obvious, at the same time, that the efficacy of this, as well as of the former, depends entirely on the nature of the soil, and the source of the moisture which it is the object of either to remove. Surface-moisture is excluded by the very structure of the Drain; for no sooner should it penetrate the clay than the tube would collapse or crumble down. But if the intention of the farmer extends no further than to convey water already collected on some particular spot to a rivulet or main Drain, the contrivance of Mr. Pearson will be found to realize his views at less expense than any other.

Wheel Drain.

The *wheel* Drain is the last we shall mention, which, though like some of the others limited in its application to particular kinds of land, is yet too ingenious to be passed over without notice. It is accomplished by means of a Draining-wheel of cast iron, weighing about four hundred weight. It is four feet in diameter; the cutting-edge or extremity of the circumference of the wheel is half an inch thick, and increases in thickness towards the centre. At fifteen inches deep it will cut a Drain half an inch wide at the bottom, and four inches wide at the top. The wheel is so placed in a frame that it may be loaded at pleasure, and made to operate to a greater or less depth, according to the resistance made by the ground. It is used in Winter when the soil is soft; and the wheel tracts are either immediately filled with straw ropes, and lightly covered over with earth, or they are left to crack wider and deeper till the ensuing Summer; after which the fissures are filled with ropes of straw or of twisted twigs, and lightly covered with the most porous earth that is at hand. In this way, upon grass or ley lands, hollow Drains, which answer extremely well, are formed at a trifling expense. It is said that twelve acres may be fully gone over with this Draining-wheel in one day, so as to make cuts at all necessary distances.*

Ridges.

These resources of Art are found availing in a great number of cases, and have contributed much to the improvement of land which otherwise would have been of very little value. Still, in many instances where the surface is flat, and the soil of a stiff and retentive nature, all attempts to free the ground from injurious moisture by means of covered Drains have proved utterly ineffectual. In most of the central Counties of England, and in the level plains of Flanders, the land is relieved from surface-water by forming high and broad ridges of twenty, thirty, and even forty feet wide, and having the centre three or four feet more elevated than the furrows. The beneficial effects of this method of Draining are fully confirmed by the successful practice of the Flemings; for when furrows are kept free from water, the fields are always dry, and the crops abundant and healthy. But in some parts of England, from the improper direction and flatness of the ridges, as well as the shallowness of the furrows, these good effects have not been obtained; for the water, stagnated in all the hollow places, and rendering them useless, has not only brought some degree of discredit on the method itself, but has also led to the adoption of other less perfect methods of Draining. The indiscriminate formation of high ridges has been justly censured, for in a dry or loamy soil they are both unnecessary and pernicious; but when they are well rounded, not too much raised, and the furrows kept clear, they afford the most efficacious means of rendering perfectly dry many fine breadths of land which could not otherwise be kept under tillage.

Draining in the Carse of Gowrie.

A device for relieving a retentive soil from water by means of surface-draining, as it is practised in the Carse of Gowrie in Perthshire, seems worthy of being recorded in this place, more especially as it is the only method employed in that rich and extensive district. Large common Drains, traversing the farm in different directions, and of sufficient capacity to receive the water conducted from the fields by the surrounding ditches, discharge their contents into the river Tay. Every farm is surrounded or traversed by ditches, so as to suit the particular situation, all of which are so directed and arranged as to form a communication with every field belonging to it. The breadth of these ditches is from two to four feet at top, and from a foot to a foot and a half at bottom, and with such a slop as to prevent their sides from falling in. If the fields be of a uniform level surface, the common furrows between the ridges, provided they have sufficient depth at their extremities, serve to carry off the redundant water. But in a field of unequal surface, the last operation, after the sowing and harrowing are completed, is to draw a furrow with the plough through all the hollows which lie in such a direction that it can be guided through them, and thus form a free communication with any of the furrows between the ridges, which last act as conductors of the water to the surrounding ditches. When this furrow is formed by the plough, it is widened, cleared out, and dressed with the spade, that the risk of filling up may be avoided. The width is from six inches to a foot according to the depth; but the breadth of a spade at bottom is generally found sufficient. It often happens that hollows or inequalities do not extend across the whole field, or pass through it in any direction to be followed by a plough, but are limited to one or two ridges; in which case the cut must be performed with the spade, and a communication effected with the nearest furrow.

Head-ridges.

In the same part of the country, it is still the general practice to have head-ridges at two extremities of the field, on which the horses turn in the process of ploughing. These are raised considerably in the middle, and slope down to a deep furrow on either side; and hence the inner furrow, communicating with those of all the longitudinal ridges, receives their surface-water, and discharges it by an open Drain, cut through the transverse or head-ridges just described, into the adjoining ditches. But it being discovered that the water passes off more freely when no transverse ridge is formed, a practice has been adopted of laying the earth uniformly to the ends of the longitudinal ridges, an operation which is accomplished by returning on one side with an empty plough. In this way the depression between the longitudinal and transverse ridges is avoided, the longitudinal furrow being carried completely through the head ridge. Besides this advantage, it has been found, after a long experience, and the trial of different other methods, that, by careful ploughing, laying up the land

* *Agricultural Report of the County of Essex.* London, p. 710.

Agriculture. equally, and rounding the ridges so skilfully that they shall be neither too high nor too low, all the surface-water is easily removed; and while the summits are not unduly enriched nor the furrows impoverished, the whole becomes equally dry and fertile.*

Tools. Draining scoop. The tools peculiar to Draining are chiefly of the spade kind. The *Draining scoop*, already mentioned, is a crooked instrument made use in some cases for clearing out the loose materials from the bottoms of Drains. It is formed of different sizes and breadths, according to the dimensions of the Drains; and in working, it is drawn or pushed along the bottom. See fig. 15.

Shovel. The *Draining shovel* is another kind of tool employed for nearly the same purpose as the scoop now described. It is made with a bent or crooked handle; the edge of the plate being turned up so as to prevent the fragments of earth or clay from falling off when lifted from the bottom of the Drain. See fig. 16.

Sod knife. The *Draining sod knife* is an implement employed with great benefit in scoring or cutting out the sward, in the initiatory process of forming a Drain. Its figure indicates that it cuts like the coulter of a plough, placed horizontally, or after the fashion of a Turkish sabre. See fig. 17.

Spades. *Draining spades* are of different sizes in breadth as well as in length, so as to follow each other, and cut the Drains narrower and narrower as they approach the bottom. An upper and a pointed Draining spade are in general use; the one for beginning, the other for completing the work, while one constructed entirely of wood is found to answer very well in peat soils. See fig. 18.

Straw-twister. The *Draining straw-twisting machine* is of a very simple construction, is easily removed, and is very useful for forming straw into ropes for filling Drains. It consists of a small wheel, the prolonged axis or spindle of which terminates in a hook on which the rope is commenced. It is commonly fixed to a portable stand, but is sometimes attached to a threshing machine. Besides the use already stated in reference to Drains, it is found extremely convenient for spinning ropes of straw, rushes, or hay, to be employed in fastening the thatch or stacks, or ricks in the barn-yard. See fig. 19.

Irrigation.

Necessity. The fertilizing effect of water is one of those natural phenomena which force themselves on the observation of mankind. It is seen, at the first glance, to be absolutely essential to vegetable life. In those climates in which evaporation is the greatest, Nature has generally provided the most plentiful supply of this fluid in rains and dews. But the rains, in many cases, occurring only at particular seasons of the year, are insufficient for the nourishment of plants during the remainder; and, hence, the art of the Irrigator becomes necessary to meet this want, and to secure the means of a more permanent fertility. Without the systematic conveyance and distribution of water, some of the richest Countries in the World could not have supported their inhabitants, and the earliest husbandmen, accordingly, must have known and practised the cultivation of land by means

Antiquity. of Irrigation. The author of the Book of *Ecclesiastes* informs us that he "made gardens and orchards, and planted trees in them of all kind of fruits; and that he made pools of water to water therewith the wood that bringeth forth the trees." In Egypt, where the regular inundation of the Nile soon taught the natives the value of this Art, we find it practised on a scale of great magnitude; and hence the canals and vast lakes excavated by that celebrated people are more praiseworthy monuments of their genius than all the Temples and Pyramids with which they have covered a large portion of their Country. From the valley of the Nile, it is believed, the knowledge of Irrigation was extended to the nations of Europe. The Greeks and Romans, it is manifest, were well acquainted with it; and the Agricultural writings of the latter, accordingly, are found to contain many allusions to the benefits arising from the watering of land. Rice, which furnishes food to a great part of the human race, could not, as is well known, be cultivated without a constant supply of water collected by Art; and therefore over the vast regions of Central and Southern Asia, the Irrigation of the soil from rivers, brooks, tanks, and wells, is a labour quite indispensable to the maintenance of a crowded population. Even in the more Southern Countries of Europe this Art is more or less practised; water being conveyed in little channels to the corn-fields, vineyards, and olive plantations. The mode of conducting it from the rivers and canals, and the measuring it out in determinate quantities, according to the wants of the soil, and the nature of the crop, forms in several districts of Italy a nice part of the Science of engineering. In Piedmont and the whole valley of the Po, the water is frequently paid for by the hour, and the utmost care is shown in economizing so precious a commodity.

Agriculture. Egyptian. Greek and Roman. Asiatic. European.

Objects. The main object of Irrigation, however, in all the intertropical climates, and even in the warmer parts of the temperate zones, seems to be merely to convey to the earth that quantity of water which is necessary for the growth and nourishment of the particular plants which it is the object of the husbandman to raise. Sometimes, as in the case of rice, the land must be saturated for successive months, and, in other circumstances it is enough if it be merely watered at intervals, during the periods of greatest evaporation. In all these cases, indeed, the main purpose is the same, namely, to supply the deficiency of water in the soil; and this creates a remarkable distinction between the Irrigation of the tropics, and that to which we apply the term in England, with relation either to our watered meadows, or the process which in some districts of the Kingdom is technically called *warping*. As to the former of these it is perfectly certain that the object is not to provide against a want of moisture in the soil, for the water is conveyed over the surface at that period of the year, the months of Winter, when there is an excess rather than a deficiency of the aqueous fluid in the earth. Nay, it is held necessary in every well-formed meadow, to drain the ground very thoroughly of all subterraneous water. Nor is this the only distinction between the two kinds of Irrigation. In the one, the water is generally allowed to stagnate until it shall have saturated the soil; in the other, it is never allowed to stagnate, but is maintained in a constant flow over the surface.

in England.

Uncertainty of its Theory. The theory of this curious process has not yet been satisfactorily explained. That the effect is not produced by the mere supply of deficient water appears, as we have just remarked, not only from the period at which the water is admitted, when in our climate the ground is saturated with moisture, but also from the fact that the effect is produced by the current being

* Elkington, *Mode of Draining*, p. 172. Appendix on Hollow Draining by Mr. Johnstone, the editor of his book.

Agriculture. kept constantly running over the meadow, and not by being allowed to stagnate and sink down into the soil. When the water is suffered to stagnate, there are produced *carices*, *junci*, and other plants of an aquatic nature; but when it is kept in motion and drained off at intervals, there shoot forth the finest grasses peculiar to the soil and climate. Neither does the fact of the deposition of mud explain the phenomenon in question, for, however much such depositions may increase the effect, it is found that water likewise, without the least perceptible sediment, may be employed with great benefit. It has been supposed that the water acts favourably by maintaining the soil at a higher temperature than it would retain if exposed to the direct action of the atmosphere. Much, however, cannot be ascribed to this cause in a current so shallow and constant as that which passes over the watered meadow. It has, therefore, been suggested that the main effect is produced by some Mechanical or Chemical agency, in a manner still unknown to us, on the plants or the soil. In these circumstances of doubt and ignorance all that the irrigator is called to do, is to mark carefully the effects which are produced, according to the variations of his practice, to admit the water at the time and for the periods which experience points out as the best, to maintain it in a current, and not in a stagnant state; and above all, to attend to the rules and precautions which the most enlightened usage has recommended.

Necessity of experience.

We may, therefore, rest satisfied with this practical conclusion, that as land may be injured by an excess of moisture, so may it, in certain circumstances, as experience has proved, be found deficient in its productive qualities from the absence of a due *proportion of it*. In all Countries Southward of the forty-fifth degree of latitude, the study of the landholder, as has been already remarked, is more frequently directed to the means of procuring aqueous nourishment to his plants than in conveying away, by drains, the superabundant supply by which the British Agriculturist is almost constantly annoyed. The success of the former during the hot season of the year, depends in no small degree on the command which he possesses of lakes or rivulets by means of which he may Irrigate his parched fields, and restore life to his decaying crops. In this Country the various processes of Irrigation are applied chiefly to the improvement of pasture lands, but there are situations also where a deposition of earthy matter from the water of a river is esteemed useful for fertilizing a sandy soil; on which account we shall treat the subject generally as applicable to both these departments of Agricultural economy, tillage and the feeding of cattle in the field or in the stall.

Quality of the water.

The quality of the water fittest for this purpose must be tried by experiment, for it is obvious that the benefit is not derived simply from an increase of moisture, but more especially, as has been suggested, from the Chemical properties of the fluid as cooperating with those of the soil on which it is spread. Let a small portion of land be floated for a month about the latter end of harvest, and afterwards for a week or two about the beginning of Spring. The effects of this easy experiment will appear on the crop, both in respect of quality and quantity, while the temperature of the water may be determined by its power of resisting early frosts, a consideration of no small consequence in this mode of improving land. The appearance of the water is not of itself sufficient to afford a criterion of its properties. Thick muddy rivers, enriched in their passage through large towns, will be found to reward the labour of the husbandman; while clear Alpine streams, on the other hand, will chill instead of fertilizing the soil on which they are detained. With regard to those waters, again, which are known to flow through beds of marl, there is reason to believe that much advantage may be gained from the use of them, in producing a sweet and rich verdure the most valuable for pasturage. Warm rivulets, containing a great quantity of spring water, and resisting early frosts, may be expected to have the same beneficial tendency. But mossy waters, darkened by the tincture of peat bogs, are very unpromising for the purposes of Irrigation; though it may be right in some cases to give them a trial, for if impregnated with marl, or spread upon grounds abounding with calcareous ingredients, they will be productive of certain benefit.*

Sir H. Davy's remarks.

It is observed by Sir H. Davy, that common river water generally contains a certain portion of organizable matter, which is much greater after rains than at other times; and which exists in the largest quantity when the stream arises in a cultivated country. But even in cases in which the water used for flooding pasture lands is pure, and free from animal or vegetable substances, it acts by causing the more equal diffusion of nutritive matter existing in the land; and in very cold seasons it preserves the tender roots and leaves of the grass from being affected by the frost. Water is of a greater specific gravity at 42° of Fahrenheit's scale than at 32°, the freezing point; and hence, in a meadow Irrigated during Winter, the water immediately in contact with the grass is rarely below 40°, a degree of temperature not at all prejudicial to the living organs of plants. "In 1804," says he, "in the month of March, I examined the temperature in a water-meadow, near Hungerford, in Berkshire, by a very delicate thermometer. The temperature of the air at seven in the morning was 29°. The water was frozen above the grass. The temperature of the soil below the water in which the roots of the grass were fixed was 43°." In general, it is added, those waters which breed the best fish are the best fitted for Irrigation. It is, however, a general principle, that waters containing ferruginous impregnations, though possessed of fertilizing effects when applied to a calcareous soil, are injurious on such as do not effervesce with acids; and that calcareous water, which is known by the earthy deposits it affords when boiled, is of much use on silicious lands, or other soils not containing any remarkable quantity of carbonate of lime.†

To pursue the subject a little more systematically, we shall consider the effects of Irrigation, *first*, as it applies to corn lands, and *secondly*, as it respects those which are used for pasture, as well as for raising crops of hay.

Irrigation on corn lands. Warping.

1. The process, as applicable to the former, is commonly called *warping*, a provincial term, the meaning of which will be best explained by the description which follows. In some districts it is justly considered as one of the principal means of improvement, adding to the value and thickness of the soil every time it is repeated. In fact, a new soil is artificially created by the operation in question, and generally one much superior in quality to the surface which it is brought to cover. It is not indeed in every situation that warping can be used, but

* Brown *on Rural Affairs*, vol. ii. p. 265.

† *Agricultural Chemistry*, p. 318.

Agriculture. wherever it is practicable it ought to be employed, if the land be not already saturated with the elements of fertility. The expense, it must be obvious, will vary according to circumstances, but even when at the greatest, it is not to be compared to the immense benefit which is thereby conferred upon thin and hungry soils.

Originated in Yorkshire. It was in Yorkshire that warping originated, and there it is still carried on to a great extent, especially on the banks of the Ouse and of the Humber. The former of these rivers, from the circumstance of receiving into its bed most of the streams which intersect the Southern parts of that County, is constantly stored with all sorts of alluvial matter; and being kept in motion by the tide which flows several miles above York, the floating earths are not allowed to deposit themselves, but are conveyed by the process of warping over the adjoining grounds, which for the most part are flat and easily flooded. Best adapted to low lands. Of all others, low land is the most capable of being improved in this manner; and while it is enriched by so simple an expedient, no injury is inflicted upon such farms as are placed beyond the reach of the benefit. Fittest seasons. June, July, and August are considered to be the best months for warping, on account of their being generally the driest months in the year; though land may be warped at any season, provided the weather be not wet, nor the fresh water in the river very low. When the season is wet, and the rivers full, the operation of warping cannot be conveniently executed, as the fresh water, mixing with the tide, dilutes the current to a great degree, and consequently renders it incapable of depositing the same quantity of sediment upon the land as takes place when the process is performed in fine weather; neither is the water got so readily off the irrigated grounds. There is no advantage in warping land in the Spring, in preference to the Summer, as no crop can be obtained the year this expedient is adopted; for the sediment must have time to consolidate and dry before the ground can be cultivated with any prospect of doing good. Warped land is supposed to be well calculated for producing potatoes, immense crops of that valuable root being raised on soils so managed, though naturally of a very inferior order.

Strict definition. From what has been stated, it will be understood that *warp* consists of the mud and salts left by the water on the surface of the fields which have been flooded; and that the technical expression *warping* comprehends all the processes necessary to admit the tide water, and to secure the deposit of its sediment upon the land meant to be improved. The letting in of fresh water would not be called warping, but simply flooding. Fresh water, though useful at proper seasons, would by no means answer the same purpose as river water stirred up by the tide; because it never could furnish a sufficient sediment for thickening the soil; neither would the sediment be of so rich a nature as what is furnished by tide water.

Mode of operation. A complete detail of the different operations in the process of warping is given in the *Agricultural Survey of the West Riding of Yorkshire*. From that Work it appears that the land to be warped must be banked against the river whence the supply of water is derived. The banks are commonly made of earth taken on the spot, are constructed in a sloping form, and are raised to such a height as to regulate the admission of water at the spring-tides. The openings are more or less numerous, according to the extent of the land to be warped; but in general there are only two sluices, the one called the *flood-gate*, the other the *clough;* the object of the first being to admit, while that of the last is to let off the water gently, during the rise and fall of the tide in the river. When the spring-tide begins to ebb, the flood-gate is opened to admit the current, the clough having been previously shut by the weight of water brought up the river by the flow. As the tide ebbs down the river, the weight or pressure of water being taken from the outside of the clough next the bank, the tide-water which has been previously admitted by the flood-gate, opens the clough again, and discharges itself slowly but completely through it. The cloughs are so constructed as to let the water run off, between the ebb of the tide that was admitted and the flow of the next; a point to which particular attention is paid, and the flood-gates are placed so high as to be above the level of the common tides, and so as to receive the water only at the springs.

Willow planting. It is not unusual to plant willows on the sloping sides of the banks, with the view at once of breaking the force of the stream, and by producing an accumulation of mud of defending them from the action of the water. But the experienced husbandman avoids all such plantations on the top of his banks, knowing that he would thereby give to the winds a great additional power, and expose his works to much serious damage.

Deposit. We need not remark that the deposit is made by the ebbing tide, as the rush from the ocean rather checks the current which comes down loaded with the spoils of the land from the higher parts of the country. Near Howden, it is said, one tide will deposit *warp* to the depth of an inch; an effect which is increased or diminished according to the distance from the mouth of the Humber. Cherry Cob Sands were originally gained from this river by warping, and are supposed to possess a deposit of alluvial sediment not less than twelve feet deep. Subsequent culture. They were ploughed fourteen or sixteen years before they became fitted for grass seeds; but now the greater part of the tract is used for pasture, and yields a most nutritive herbage. Grass-land, we are assured, is not warped a second time, until the plants are found beginning to wear out; upon which the process is commonly renewed, the water is again admitted, the plough once more stirs its surface, and a succession of corn crops are drawn from the renovated soil, before it reverts, as in the first instance, to the uses of pasture. It is true that the best mode of cultivating warped lands must depend principally on the nature of the matter deposited as well as of the subsoil. In the *Code of Agriculture*, it is recommended to sow such grounds with clover, and to let it lie under that crop for two years, in order that it may be brought into a fit state for corn. Even though fallowed, it does not answer to sow land with wheat immediately after it has been warped; but after white or red clover for two years, a good crop of wheat may generally be relied on. Nor is it proper, says the same authority, when land is warped, to plant it with potatoes, or to sow it with flax; being at first of too cold a nature; though if the land be not too strong for potatoes, these crops may answer, after it has been two or three years under cultivation. Quality of the land. In the quality of warped land, we need not add, there are most essential differences; some is found very strong and some very friable even in the same field. The portion nearest the sluices and the general run of the water, is commonly the lightest, owing to the quantity of sand that is deposited as soon as the current enters the enclosure; while that furthest from

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the river bank is usually the best, as the deposit takes place more undisturbed, and in much greater abundance.

South of France and Italy.

The Irrigation of arable land, as we have repeatedly observed, is universal in warm Countries, and even in the South of France and Italy. It is laid out in narrow beds, between which the water is introduced in furrows during the growth of the crop and absorbed by the soil. The principal expense of the operation is that of preparing the ground by throwing the surface into a proper level. The main run, or carrier, as it is called, is conducted to the highest part of the field, and all the rest is easy. In the *General Report of the Agriculture of Scotland*, it is stated, that a field of waste land, which had been flooded during Winter with stagnant water, was thereby rendered capable of bearing a plentiful crop of oats, without the use of any species of manure. But this process, it has been justly observed, partakes more of the nature of warping than of simple Irrigation, particularly as the latter is practised in India, and in the Southern parts of Europe, during the course of vegetation.

Subterraneous Irrigation.

There is a species of Irrigation which is denominated *subterraneous*, to distinguish it from that which has just been described. It appears to have been first practised in Lombardy, and is mentioned by Professor Thouin, in the *Annales du Musée*. As its name imports, it consists in saturating the soil with water from below, and is effected by surrounding a piece of ground with an open drain, and intersecting it by covered channels of smaller dimensions. If the field is one level, as happens in most cases where this system is adopted in Italy, nothing more is necessary than to fill the drain, and to keep it full till the land has been sufficiently soaked. But if it lies on a slope, then the lower ends of the smaller drains must be closely stopped, and the water admitted only into the main one on the upper side; this last must be kept full till the land be saturated, when the mouths of the lower drains may be opened to carry off the superfluous water. The practice is applicable either to pasture or to arable lands, under a climate more distinguished for heat than moisture.

In Britain.

In our own Country subterraneous Irrigation has been applied, in a very simple manner, to drained bogs, morasses, and fen lands. All that is necessary is to build a sluice in the lower part of the main drain, where it leaves the fields to which attention is directed, and in dry weather to shut this sluice, so as to dam up the water and throw it back into all the subsidiary drains, whether covered or uncovered. This method has been introduced with great advantage in various parts of Scotland, and also in Lincolnshire, where extensive drainages have lately been accomplished.

Irrigation of grazing lands.

2. But in these Northern latitudes, Irrigation is much more frequently applied to grazing-grounds than to such as are meant for tillage. For the former, the original quality of the soil is of little importance; wherever the water deposits a good deal of sediment, the natural poverty of the surface being soon fertilized by the enriching ingredients with which it is imbedded. This observation, it is true, respects the meadows of England more directly than the artificial pastures of Scotland; for, in the latter Country, the streams for the most part descend from barren hills, and, accordingly, convey hardly any other deposit than silicious sand and coarse gravel.

The author of the Work entitled *Rural Affairs*, who has evidently bestowed much attention on the Irrigation of various soils, recommends to his readers the following results as the fruit of experience. He has found that perennial red clover prospers in watered meadows, having a due proportion of marl or lime in the land itself, or in the water with which it is moistened, while the common broad red clover speedily dies out; that the plants of *Holcus lanatus*, the soft, vernal, woolly, meadow grass, prosper in any soft soil, especially if it be also watered; that *Poa trivialis*, the rough-stalked meadow grass, delights in the soils last mentioned, if they are possessed of a degree of moisture between loam and bog; that *Cynosurus cristatus*, the crested dog-tail grass, thrives extremely well in watered loams, although Botanists seem not aware of this fact; that *Anthoxanthum odoratum*, scented vernal grass, will hardly fail in any watered meadow where it has been once established, however coarse may be the soil, adding not only to the bulk and weight of hay, but communicating the sweetest odour to the whole crop, if made in dry weather; that the genus of grasses, called *Agrostis*, or *bent*, furnishes two species which are very good plants in watered meadows, the *Agrostis alba*, and the *Agrostis stolonifera*; that in loams completely broken with the spade, and then watered, *Triticum repens*, couch or quick grass, forms a valuable plant for hay; and that for soft peat bogs, no plant yields more hay than the common spratt, the *Juncus articulatus*, which in richly watered meadows comes forward very early, and would scarcely be known, if mown before feeding, by those who never saw it cut in proper time.

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Various grasses produced.

"All these plants," says Mr. Brown, "are adapted to furnish a crop of hay, and also to yield a very abundant pasturage; but at present they can hardly be obtained in the seed-shops, excepting perennial red clover, which is sold under the name of marl grass. A farmer must have a portion of good grass, or purchase it from others; leaving it to stand till the seeds are mostly ripe, and then taking care to preserve these for sowing in his new meadow grounds. I have not often met with perennial rye grass in watered meadows, and am inclined to think that it does not prosper there; but as I know that it will stand for a season or more, it may be soon intermixed, and will thicken the grass in the mean time."*

Season.

The water should be let on early in the month of October. The effects of this watering are very important in strengthening the roots and stalks of plants, and preparing them for vigorous shoots in the Spring; and the blades that now rise form a rough coat against Winter, protecting the more delicate organs of the vegetable frame from the severity of that season. It sometimes happens, also, that by delaying the process too long early frosts supervene, and very much impede, or even entirely defeat, the main object of the operation. If the land be rich, it will generally be found that three weeks are sufficient for the first turn; but if it be sour and coarse, four weeks may be necessary. The verdure will then be fine, and the soil rich and yielding.

Method of conducting water.

To apply Irrigation judiciously to meadow land, a stream of water must be conducted to the surface and made to flow over it in a constant manner; it being understood that the grounds to be so treated lie upon the banks of the river from which the supply is to be conveyed, and forming a flat surface, or rather a gently inclined plane. To the highest part of this inclined surface, the water is led in what is termed the main conductor, either by building a wear or dam across the river where the water is to be taken off, or by bringing

* Brown, *On Rural Affairs*, vol. ii. p. 263, &c.

Agriculture. it by means of a cut from a higher source. In fig. 20, A represents the main-conductor, and B the wear or dam.

From the main conductor, and as nearly as possible at right angles to it, are taken off the various feeders, C, C, C, &c. These consist of small trenches a few inches in depth, made widest when they issue from the main conductor, and gradually lessening as they recede from it. They may be formed at the distance from each other of forty feet or less, being closer where the soil is stiff and retentive, and further distant where it is loose and porous. By this means the water is conveyed to the surface of the meadow. But as it is necessary that it should maintain an equal flow over the ground, and so be carried off as quickly as it is admitted, the main drain D, D is formed at the lower part of the meadow, and the smaller drains E, E, E pass in the intervals between the feeders, in the manner exhibited in the diagram already referred to. These small drains are of the same dimensions as the feeders, but are larger where they enter the main drain, and become gradually smaller as they recede from it. The main drain conveys the water back to the river from which it was taken; but in many instances, this drain becomes, in its turn, the main conductor to another meadow on a lower level. The water which had floated the upper meadow being collected in this drain, is carried off from it by means of feeders in the manner described, and again collected in a drain below; and, in this manner, various meadows are successively irrigated by the application of the same water. Even where the lower meadows are nearly on the same level as the higher, it is still expedient to resort to this repeated collection of the water in drains; for, in practice, it is found difficult to preserve the equal flow of the moisture over a large breadth of ground.

In order to keep the water as it descends through the feeders at the necessary level, and to cause it to overflow the surface, it is interrupted in its progress by what are termed stops, placed in the feeders. These sometimes consist of small pieces of plank, each resting on two little stakes. But oftener they are merely sods thrust into the feeders and occasionally fastened with wooden pins. It is the province of the person who superintends the meadows, when floated, to adjust these stops in such a way as to maintain an equal current over the whole surface. Further, in order to convey the water quickly from the feeders to the drains, the face of the meadow is generally moulded into low ridges, the feeders being on the top of the ridge and the drain in the hollow, so that a transverse section would appear, as in fig. 21; *a* representing the feeder, and *b b* the drains. In the language of the scientific Irrigator, the interval from *b* to *a* is termed a *pane;* and in fig. 20, the space *i i*, which is left for a carriage way above the main conductor, is denominated the main pane, and is watered from that conductor.*

On grounds much inclined. Such is the most perfect form of the watered meadow. But when the inclination of the plane of the surface is considerable, a different principle must be adopted as regards the conveyance and distribution of the water. In this case the feeders are not carried longitudinally through the meadow, but across the line of the descent, in the manner represented in fig. 22. Here the several feeders are filled as before from the main conductor, but when they overflow their banks instead of discharging their water into the smaller drains, they throw it into the next feeder lower down; and thus the fluid is conveyed from feeder to feeder over the entire space of the meadow. This species of Irrigation is termed *catch work;* and, as it can be applied where the surface is too much inclined to admit of the flat meadow, it is frequently practicable where the other is not, and is often combined with it on the same ground, where there are swells or considerable inequalities.

Periods. We have remarked above that the process of floating generally commences in the month of October, being as soon as possible after the later grass is consumed, or the second crop of hay removed. The water is kept in the ground from fifteen to twenty days at a time. It is then let off, and the meadow laid perfectly dry during five or six days; and this process of alternate flooding and drying is continued generally in the months of November, December, and January; care being taken to remove the water whenever it begins to freeze. As the Spring advances and the grasses shoot forth, the periods of watering are shortened so that the flooding shall not last above five or six days at a time. In the Southern Counties of England, the meadows are ready for the reception of stock of all kinds in the middle of March; but further to the North, where the grasses do not make such early progress, Irrigation is usually continued during the whole month of May. After this it is discontinued for the season, and a crop of hay, sometimes two, are produced to reward the farmer for his pains. Flooding is rarely practised during the Summer months, though the admission of water at that season occasions a rapid and profuse vegetation. It is suspected that it is by Summer flooding the fatal disease of rot is introduced; and accordingly the experienced Agriculturist does not permit his sheep to graze on the meadows which have been covered with water any time between May and September.

Roman knowledge of Irrigation. England, it has been remarked, is the natural Country of the watered meadow; being perhaps the only one where the practice of the Art is understood and carried on as a regular branch of rural labour. There is no room to doubt that this branch of knowledge, like many others, was derived from the Romans. For though in modern Italy the Irrigation practised seems merely designed to convey water to the soil, yet from various remarks in the writings of the ancient authors, it would appear that those illustrious husbandmen were acquainted with the principles of that more artificial process of which we now speak. It is well known that a great preference was given by many of the Romans to the meadow as compared with corn land, as being more profitable to the occupier. The maxims of the elder Cato on this subject, have been handed down to us, and are often quoted. He speaks frequently of the watered meadows: *Prata irrigua, si aquam habebis, potissimum facito; si aquam non habebis, sicca quam plurima facito.* "If you have water irrigate as many meadows as possible; if you have not water, make as many dry meadows as you can." Pliny, Columella, and Palladius express themselves to the same effect. But to whatever skill the citizens of Rome may have attained, prior to their conquest of Britain, there are circumstances peculiar to England which have conduced more to its perfection here than even in Italy, where, in our days at least, natural meadows are more rare, and where all that is required to fulfil the highest purposes of the husband

* Stephens, *Practical Irrigator. Quarterly Journal of Agriculture*, No. VI. p. 781.

Agriculture. man is to convey a little water, no matter how, to the parched surface of his fruitful soil. This Country is, in particular, admirably suited to the production of the common grasses. These appear in a variety of species unknown in more Southerly climates, and grow with a closeness and vigour unparalleled in higher latitudes. The rivers, too, especially in those Counties most celebrated for this branch of husbandry, are generally turbid, and, flowing through fertile and cultivated districts, are enriched with the animal and vegetable matters which they receive in their progress, and thus not only irrigate, but positively manure the lands to which they are conveyed. Gloucestershire and Wilts have long been celebrated for their superior Irrigation; and there are now other divisions of the Kingdom not inferior to them in the extent and perfection to which the practice has been carried.

Irrigation not much practised in North of Britain.

In the Northern Counties of England, as well as in those beyond the Tweed, this mode of improving land has not hitherto been very generally adopted. Perhaps the diminished temperature is unfavourable to Irrigation; while the rivers, rushing over a rocky bed and between precipitous banks, do not afford the same facility for inundating, in a regular, periodical manner, the adjoining fields or meadows. An attempt was made in Dumfriesshire some years ago; but the result, owing to ignorance and prejudice among the tenantry, or perhaps to local peculiarities which could not be controuled, was very little encouraging. The vicinity of Edinburgh, we are informed by Mr. Stephens, presents almost the only exception in Scotland to the remark just made in reference to want of success in the processes of Irrigation. About two hundred acres moistened by the common sewers of the city, "produce crops not to be equalled, being cut from four to six times in the year, and the grass given to milch cows." The annual rent of those meadows ranges from £20 to £40 per acre, according to the convenience of the situation, and the care bestowed on the land; nay, he mentioned an instance in which the price rose so high as £57 the acre, for a single Summer.*

Edinburgh.

Manures.

Division.

No sooner is land relieved from the deteriorating effects of superfluous moisture, than it is fitted for the application of those animal or vegetable substances which, when reduced to a putrescent state, are known under the general name of Manures. Our limits will not permit us to enter into the minute details which might be desired by the practical Agriculturist; but whatever deficiency may appear to arise from the abridged nature of our plan will, we hope, be amply compensated by copious references to the best authors who have treated this important subject. To assist the comprehension of the reader we shall arrange our observations under the five following heads: Calcareous, Earthy, Vegetable, Animal, and Miscellaneous.

Calcareou Manures. Lime.

The most common form in which calcareous matter appears is that of lime, a substance than which there is none more familiar, whether as an article employed in the Arts, or as used for the purpose of improving land. As it exists in Nature, it is always in a state of combination with an Acid, the carbonic or sulphuric, and not unfrequently with clay and silicious earth. When limestone is subjected to a strong heat, the gaseous matter with which it is combined is expelled, and it is found to have lost a portion of its weight equal to that of the elastic fluid which has escaped. When the burned mass is exposed to a moist atmosphere, it absorbs water, swells, and falls down into a powder, denominated quick-lime, and which is more or less pure according to the nature of the stone. It has, moreover, acquired new properties. Limestone, although pounded down to a fine sand, has no perceptible effect on animal or vegetable matters; but burned or calcined lime is extremely acrid and corrosive; and hence the distinctive characters of this mineral in its two states as *mild* and *caustic*.

Estimate of purity.

As limestones have very different degrees of purity, it is obviously of the highest importance to ascertain the quantity of calcareous matter which enters into their composition. In general, then, it may be observed, that the greater the loss of weight which they sustain in burning the larger is the proportion of pure lime. A pretty accurate estimate may be made of the quantity of calcareous matter in any limestone, by observing first, how much diluted nitric or muriatic Acid is required for the complete saturation of a determinate portion of the purest limestone; and secondly, by ascertaining how much of the limestone to be examined will saturate an equal amount of the same Acid. If in the latter case a double quantity is found necessary, then the stone contains only half the quantity of the calcareous earth which is in combination with the purer specimen. But practical Agriculturists usually have recourse to a simpler and more obvious test; which consists in the measurement of the burnt lime in the unslaked state, as compared with its bulk in the state of powder after it is slaked; the latter being three times the volume of the former when the limestone is of a good quality.

Soils.

The soils which are most improved by the use of lime are those usually denominated cold and stiff, such as strong clays and deep loams, or such as are combined with a large proportion of vegetable matter, but contain no calcareous earth in their composition. It may, indeed be regarded as advantageous to all lands except such as display sandy or calcareous ingredients. Considerable diversity of opinion prevails indeed as to the time and circumstances in which lime ought to be applied. But, in whatever way it operates, whether by its mechanical effects on the soil, altering its consistence and texture, or by certain Chemical changes on the organized matter contained in the Globe, there can be no doubt that, in order to produce the desired result, it must be equally and uniformly distributed over the surface of the field. To ensure this object, the lime must be in the form of powder, and in as dry a state as possible. For this purpose the calcined stones should be laid together in considerable heaps; and as they absorb moisture from the earth or atmosphere, they gradually swell and fall to pieces. Might it not be suggested as a useful and convenient method for the equal application of lime to mix it carefully with a quantity of dry earth? and if mould of a different nature from the soil to be improved could be easily obtained, the increased value of the compost as a means of fertilizing the land, would doubtless be an ample compensation for the additional labour and expense.

Mode of application.

As lime cannot produce its effects without being intimately mixed with the soil, it follows that it should not be applied except when the latter is dry, and in as complete a state of pulverization as can be accomplished by the operations of tillage. Another general rule to be

* *Practical Irrigator.*

Agriculture.

observed in the use of this Manure, is that it should be mixed with the soil near the surface. The most proper time for its application, therefore, seems to be when the operations of fallowing are concluded, when it may be either harrowed in, or covered with a very light ploughing. On the same principle lime is best applied to lands destined for turnips, wheat, and similar crops, immediately before the deposition of the seed, so that a moderate harrowing is the only operation which remains to be performed. Repeated ploughings are recommended by some authors for the purpose of mixing calcareous Manure thoroughly with the soil; but there is no small risk that a part of it shall be thereby carried down beyond the reach of vegetation, an effect very frequently produced when grass lands are limed and then subjected to a deep furrow.

Season for top-dressing.

When lime is to be used as a top-dressing for pasture land, it should be applied early in the Spring or Autumn, rather than in Summer or Winter; because in hot weather the grass is apt to be burned up, while in Winter the effects of this Manure are supposed to be diminished by the frost.

Renewals.

It is deserving of notice that great care is requisite in renewing the application of calcareous matter to the same field, even at a considerable distance of time; for it has been found that, on soils where it produced, in the first instance, the very best effects, the repetition of it, in the same quantity, has either not been attended with any beneficial result, or with one positively injurious. Hence it has become in many parts of the country an established maxim to apply lime in proportions constantly decreasing, and always in the form of compost with other earthy or animal substances.

Quantity.

No precise rule can be laid down as to the quantity of this Manure which should be applied to every particular species of land. The general practice seems to proceed on the principle that light, sandy, or loamy, require a smaller portion than stiff clays; but in no case is the determinate quantity accurately ascertained. The quantity employed in some parts of the Kingdom, and on certain soils, ranges from five hundred to a thousand bushels for the imperial acre; though the average may be estimated at rather less than two hundred bushels. In the Peak of Derbyshire, the largest proportion just mentioned is not unfrequently expended on the heaths and moorlands, by means of which they are converted into excellent pasture. But it has been justly remarked that, in many instances, though an overdose of lime does no harm, it is not beneficial to the full extent, and therefore can only be regarded as an injudicious expenditure.

Mixture with magnesia.

The caution now recommended is more necessary in those parts of the country where the limestone is mixed with magnesian earth, which never fails to have a deleterious effect on the crops. It communicates to the calcined powder an extremely caustic quality, whence it has usually been distinguished both by the mason and the farmer, as *hot lime*. Mr. Tennant was the first who traced this corrosive action to the presence of magnesia in the form of a carbonate. The quantity employed as Manure ought not to exceed thirty bushels the acre, except where there is, in the land, a large proportion of vegetable matter not fully dissolved, in which case the dose may be somewhat increased. When the magnesia is mild, or in other words, has not been burned, it is acknowledged to be a useful ingredient in the composition of soils. The Lizard Downs in Cornwall, which bear a short, green grass, and afford an excellent pasture for sheep, contain a considerable quantity of mild magnesian earth.

Theory of operation.

It is remarkable that, although the good effects of lime properly applied are so obvious as to recommend it to the Agriculturist as one of the most useful Manures, its mode of operation, whether on the soil or plants, remains still a secret. Numerous speculations have been indulged in regard to it; but until Chemistry and Physiology shall have made further advances in unfolding the changes which take place in the qualities of the mould, and in developing some of the mysteries of the vegetative process, we must consider the whole as only doubtful conjecture. "When lime," says Sir Humphry Davy, "whether freshly burned or slaked, is mixed with any moist vegetable matter, there is a strong action between the lime and the vegetable matter, and they form a kind of compost together, of which a part is usually soluble in water. By this kind of operation, lime renders matter, which was before inert, nutritive; and as charcoal and oxygen abound in all vegetable matters, it becomes at the same time converted into carbonate of lime. Mild lime, powdered limestone, marls and chalk have no action of this kind upon vegetable matter; by their action they prevent the too rapid decomposition of substances already dissolved, but they have no tendency to form soluble matters. It is obvious from these circumstances that the operation of quick-lime, and marl, or chalk, depends upon principles altogether different. Quick-lime, in being applied to land, tends to bring any hard vegetable matter that it contains into a state of more rapid decomposition and solution so as to render it a more proper food for plants. Chalk and marl, or carbonate of lime will only improve the texture of the soil, or its relation to absorption; it acts merely as one of its earthy ingredients; quick-lime, when it becomes mild, operates in the same manner as chalk, but in the act of becoming mild, it prepares soluble out of insoluble matter. It is upon this circumstance that the operation of lime, in the preparation for wheat-crops, depends, and its efficacy in fertilizing peats, and in bringing into a state of cultivation all soils abounding in hard roots, or dry fibres, or inert vegetable matter."

Pounded limestone.

In cases where caustic lime is not found to answer, the farmer sometimes applies pounded limestone, which, as has just been suggested, improves the soil by becoming one of its earthy ingredients. The scrapings or dust of roads formed of this rock have been used with advantage as a Manure, in Yorkshire, Gloucestershire, and other districts; a circumstance which leaves no doubt, that were machines employed for grinding the carbonate into a powder sufficiently fine, the consistence of much indifferent land might be greatly ameliorated. On the same principle, the dust of marble-works and even the smaller fragments in limestone quarries, have been found beneficial, in the absence of more active calcareous elements.

Limestone gravel.

Limestone gravel has been found an excellent Manure for peat-bogs; its weight consolidating the loose soil while its fertilizing qualities augment the produce. It has proved of immense benefit to Ireland and also to some parts of Scotland. Chalk, we need hardly observe, is used to a great extent in the Southern and Eastern districts of this Kingdom, where it presents itself in great abundance. It is frequently applied in a crude state, spread upon the surface in Autumn, and left to be dissolved by the frost during the Winter.

Agriculture. Five or six waggon-loads per acre produce a very beneficial effect; though, when calcined, two hundred bushels may be allotted to the same extent of ground, and even repeated every three or four years.

Marl. Of *marl* there are usually reckoned four kinds, rock, slate, clay, and shell. In Lancashire and Cheshire, clay-marl is very much used by the farmer, who does not grudge a considerable degree of labour and expense in order to obtain it. The quantity laid on the ground, from time to time, appears enormous; amounting, in many cases, to three hundred cart-loads per acre, which give to the fields the semblance of a red-soiled fallow freshly ploughed. Shell-marl consists entirely of calcareous matter, being the broken and partially decayed remains of testaceous fish. It may be applied as a top-dressing to wheat and other crops when it would be hazardous to use quick-lime.

Sea-shells. *Sea-shells* abound in various parts of the British Isles, and are frequently collected as a Manure. They are superior to the usual sorts of limestone in purity, and in the proportion of calcareous matter which they contain. These shells have not, however, unless when burned, an equally rapid and powerful influence on the soil. When not calcined they are much improved in their effects, if broken in a mill resembling that used by tanners for bruising their bark; the air which is thereby admitted accelerating their decomposition and consequent mixture with the proper ingredients of the field. Sea-sand having a mixture of shells is also used with much success on the shores of Yorkshire, Devonshire, Cornwall, Caithness, and Aberdeen. It is particularly beneficial in strong clays, as both its component parts, sand and shells, have a powerful tendency to improve a stiff soil.

Gypsum. *Gypsum*, or the sulphate of lime, when applied to the cultivated grasses, is generally found to reward the labours of the husbandman. The ashes of sainfoin, clover, and rye-grass, when those plants are calcined, afford this substance in considerable quantities; and hence it has been inferred that it constitutes a necessary part of the woody fibre of those grasses. Cultivated soils in general contain enough of it for the grasses they produce; but where there is any deficiency, fields which have ceased to bear good crops of clover and other artificial grasses, may, it is presumed, be restored to their former fertility by a suitable application of this mineral.

Earthy Manures. 2. The *Earthy Manures* are of a very simple nature, and do not require any scientific explication either as to their ingredients or use. We have already intimated

Clay. that clay is sometimes advantageously employed in improving the texture of a loose sandy soil; the quantity being determined by the degree in which the argillaceous properties are absent, in every particular field which requires to be so treated. Burned clay has likewise been long known as an excellent expedient for fertilizing grounds on which other Manures have exhausted their efficacy. In a comparative experiment, made in Galloway, of raising turnips by means of stable-dung and of clay-ashes, the crop in the ground manured with the ashes sprang earlier, was more vigorous, and the turnips were double the size. In another experiment in the same district, a very abundant crop of turnip was obtained. The quantity employed varied from thirty to fifty cart-loads per acre. Mr. Parsons, near Sherborne, applied from fifty to sixty bushels to the acre, on a cold, wet, cohesive soil. Mr. Buckley, in the neighbourhood of Loughborough, employed about seventy cart-loads to the acre of a stiff soil, in which he thought its effects in improving the texture and communicating permanent fertility were more striking than in any other instance which fell under his observation. The ashes of burned clay have also been applied as a top-dressing to grass lands, and are said, when spread at the rate of forty tons to the acre, to produce very striking effects.

Sand. *Sand*, as has also been suggested when treating of calcareous substances, is now commonly used for improving the composition of stiff clayey soils. But sand, taken from the mouths of rivers or the shores of the ocean, as it frequently contains a portion of animal and sometimes of vegetable matter, is the most likely to promote their fertility. The sands of flat shores, covered with water only during high spring tides, and which are strongly impregnated with common salt and other saline ingredients, are in some places washed for the extraction of the salt, and afterwards spread on the land as manure.

This double manufacture is pretty general on the Northern side of the Solway firth; and it is manifest that the latter practice might be advantageously adopted in many other situations. The rubbish of houses, too, which is usually a mixture of sand and lime, with other earthy and occasionally saline material, constitutes a valuable Manure, and in all cases ought to be carefully collected and preserved. Loam, mould, or any mixture of different earths with a portion of organized substances, when added to a sterile soil of a different quality, produce during a few seasons the most beneficial effects.

Peat-ashes. *Peat-ashes* have long been celebrated as an efficient Manure in several parts of England, especially in Berks and Wiltshire. They contain a considerable proportion of gypsum, together with calcareous, aluminous, and silicious earths, the sulphate and muriate of soda, and sometimes a little of the oxide of iron. Dutch ashes, which are highly recommended by Sir John Sinclair, in his *Account of the Husbandry of the Netherlands*, are composed of nearly the same ingredients, and are applied as a manure to clover which is succeeded by wheat. Nineteen bushels to the English acre afford an abundant crop of both. Burned peat is applied as a top-dressing for cultivated grasses, particularly sainfoin and clover, at the rate of from thirty to forty bushels per acre. Nay, we find that the dust of dried rotten peat is in some soils an excellent manure for potatoes. It is cut to pieces as if intended for fuel, and after being exposed to the atmosphere for some time, is laid upon the land.

Coal-ashes. *Coal-ashes*, too, although rarely employed unmixed with other substances, afford an abundant source of Manure in the neighbourhood of all large towns. The ingredients of these ashes vary in their nature and proportions according to the quality of the mineral whence they are produced; but they consist generally of aluminous and silicious earths, with a small quantity of lime and sometimes of magnesia. They are found to be highly beneficial in correcting the tenacity and opening the texture of clayey soils. They are of particular use in the neighbourhood of London, for improving those lands from which bricks have been dug. After spreading the ashes on the clay bottom, horsebeans, or some variety of the garden bean, are planted; and sometimes such grounds are laid down in grass. When applied as a top-dressing to clover, March or April is the best season, and the quantity should not exceed sixty bushels to the acre.

Ooze. Under the head of Earthy Manures, we may class the ooze, mud, or warp, which is procured at the mouths of

Agriculture. rivers, in ponds and canals. It is of a most enriching nature, and adds to the staple of the soil. It is used as a top-dressing in Spring for crops both of grain and grass, more especially for the latter; being at the same time an excellent material for composts. The late Duke of Bridgewater made considerable use of sea-ooze, brought up from the Mersey, in barges, by his canal, to lands near Worsley. It has been remarked, that wheat raised by means of this Manure is little subject to rust, mildew, or any other distemper. In respect to the mud of ponds and fresh-water streams, the value of it depends upon the substances with which it is mixed. Where the water is resorted to by cattle or fowl, or receives the washings of towns and farm-yards, or even the drainage of a rich tract of country, it will display considerable fertilizing powers, and amply repay the expense of collecting. In the Netherlands, the gardeners maintain that the mud of canals and rivers is much improved in its quality, when it has been exposed, in small heaps, to a Winter's frost and a Summer's sun before being applied to use.

Vegetable Manures. Ploughing down green crops. 3. In giving a list of *Vegetable* Manures, we naturally begin with that which is produced by ploughing down green crops, such as clover, buck wheat, vetches, beans, turnips. When this method is adopted, a portion of lime, or of peat and lime mixed together, should be spread on the field before the succulent plants are turned down; a process which ought to be performed in the Summer or early part of the Autumn, that the decay of the vegetable fibres may be more speedily promoted. In cases where Manure is scarce, this practice may be found useful; but it has been suspected that, on the whole, its advantages are doubtful, for although the quantity of nutritive matter may be increased, the expense of the acquisition seems too great.

Sea-weeds. *Sea-weeds*, in some districts, are a most important Manure, and when used with judgment never fail to enrich the land, though the effects, it is admitted, are not very lasting. They may be procured either by cutting them from the rocks, or by gathering the leaves and branches which are cast ashore by the tide; in both cases, they ought to be ploughed down without loss of time, as their efficacy appears to depend in no small measure upon the degree of freshness which they possess when mingled with the soil. The value of this Manure in improving old pastures is generally admitted. Both cattle and sheep eat with avidity the new grass which is thereby produced, thrive well, and fatten quickly.

Weeds. *Weeds*, taken from rivers, ponds, and ditches, when properly decomposed, form an ingredient of a very fertilizing compost. The heaps should be thrown together as lightly as possible, and sprinkled with water in a dry season. A small quantity of lime, or of peat earth, mixed with them, during the process of solution, not only increases the bulk, but adds materially to the value of the Manure. The more intelligent farmers confine the use of this material to fields prepared for barley, or for turnips, to be sown broad-cast.

Malt-dust. *Malt-dust* has also been found very beneficial to soils of a certain description. It is much improved by being spread for some time in the bottom of pigeon-houses, in farm yards, and also in such tanks as receive the urine of cattle, the moisture of dunghills, and the refuse of the kitchen and wash-house. It is usually sown by the hand, when in a dry state, to the extent of about thirty bushels an acre, and harrowed in with the seed, whether barley or oats.

Rape-cake. *Rape-cake* has long been used in this Country, especially in Norfolk and Yorkshire. Half a ton for an acre was formerly the amount applied to arable land; but since the price of the article has increased, the rate is reduced to one ton for three acres. Mr. Coke of Holkham makes a single ton suffice for five or six acres, by breaking the cake into very small pieces, and ploughing it in about six weeks before the time of sowing, that it may be completely dissolved in the ground. When ploughed in with wheat seed, the effect is very striking in a speedy and vigorous crop. This Manure is very extensively used in the Netherlands. It has been found that, when powdered and strewed on the surface of a field, it destroys the *Gryllus talpa*, so injurious in wet soils; and it is imagined that every insect might be exterminated by the same means. A ton of oil-cake, whether from rape or any other seed, mixed with twenty or thirty tons of dunghill compost, constitutes an excellent manure.

Tanners' bark. *Tanners' bark* has been recommended by certain authors as a substance which may be rendered nutritive to plants. For this purpose it must undergo the process of fermentation, which is most easily accomplished by forming it into a compost with stable dung. The addition of a little lime cannot fail to assist in the disintegration of the woody fibres.

Wood ashes. *Wood-ashes* have been already alluded to, under the head of Earthy Manures. They are peculiarly well calculated for gravelly soils and loams. Forty bushels per acre is the common quantity, and Spring is the proper season for their application. The effect is much increased by moisture, whether natural or artificial, which seems necessary, either as a menstruum or a vehicle, for communicating the fertilizing qualities. It has been remarked, that whatever passes through the fire acquires the power of exciting or increasing the productive properties of land.

Animal Manures. 4. *Animal substances* are usually so soluble in their nature as not to require any chemical preparation to fit them for the purposes of Manure. The great object of the farmer, on the other hand, is so to blend them with the earthy constituents in a proper state of division, as to prevent their too rapid decomposition. Much of this species of Manure is lost in many parts of the country from want of proper attention, or perhaps from ignorance of its value. Animals that have died accidentally, or in consequence of disease, are often suffered to remain exposed to the air, or immersed in water, till they are destroyed by beasts of prey, or entirely decomposed by the action of the atmosphere; and in this case, most of their muscular substance is lost for the land in which they lie, and wasted in the production of noxious gases which pollute the surrounding air. By covering dead animals with five or six times their bulk of soil mixed with one part of lime, and suffering them to remain a few months, their decomposition, as Sir H. Davy remarks, would impregnate the land with soluble matters, so as to render it an excellent manure; and by mixing a little fresh quick-lime with it, at the time of its removal, the disagreeable effluvia would be in a great measure destroyed, and it might be applied with much advantage to any of the stronger species of crops. (Dead animals.)

Fish. *Fish* forms a powerful Manure in whatever state it may happen to be used; but, however small may be the quantity applied, it cannot be ploughed in too fresh. Herrings have been known to produce a very rank crop of wheat. The refuse pilchards are employed throughout the County of Cornwall with excellent effect. They are usually mixed with sand or soil, and sometimes with

sea-weed to prevent them from communicating an excessive luxuriance to the grain. In the fens of Lincolnshire, Cambridgeshire, and Norfolk, the little fish called sticklebacks are caught in the shallow waters in such quantities, that they form a great article of Manure among the neighbouring Agriculturists. It is easy to explain the operation of fish in fertilizing the ground. The skin is principally gelatine, which, from its slight state of cohesion, is readily soluble in water. Fat or oil is always found in fishes, either under the skin or in some of the viscera; while their fibrous matter contains all the essential elements of vegetable substances.

Blubber.

Blubber, an article nearly related to that just described, has been occasionally employed as a Manure. It is most useful when mixed with clay, sand, or any common soil, so as to expose a large surface to the air, the oxygen of which reduces it to soluble matter. It has been known to retain its fertilizing power during a succession of years. The carbon and hydrogen abounding in oily substances fully account for this effect; and their durability is easily explained by a reference to the gradual manner in which they yield to the action of air and water.

Bones.

Bones are now much used as a Manure all over the Kingdom, and especially in the neighbourhood of the Metropolis. After being broken and boiled for grease, they are sold to the farmer. As their effects are more powerful in proportion to the minuteness with which they are divided, the expense of grinding them in a mill would probably be repaid by their increased value; while in the state of powder they might be used in the drill husbandry, and deposited with the seed in the same manner as rape-cake.

Horn.

Horn, regarded as the means of improving the soil, is still more efficacious than bone, as it contains a larger quantity of decomposable matter. The shavings of horn, too, form an excellent Manure, though they are not sufficiently abundant to be in common use. The animal matter in them seems to be of the nature of coagulated albumen, and is slowly rendered soluble by the action of water. The earthy principle in horn, and still more that in bones, prevents the too rapid decomposition of the animal substance, and gives great durability to its effects in strengthening the soil.

Hair, &c.

Hair, *woollen rags*, and *feathers*, which are similar in composition, consist chiefly of a substance resembling albumen united to gelatine. The theory of their operation as Manures refers to the same principles as that of horn and bone. The refuse of the different manufactories of skin and leather,—such as the shavings of the currier, and the offals of the tan-yard and glue-maker,—is found very serviceable to the Agriculturist. Blood, too, as it contains certain quantities of all the elementary ingredients detected in other animal substances, possesses a highly fertilizing quality. The scum taken from the boilers of the sugar-baker, and which is used as Manure, consists principally of bullock's blood, employed for the purpose of separating the impurities of the raw material, by means of its albuminous matter coagulated by the heat. The different species of corals, corallines, and sponges, must be considered as substances of animal origin. They contain a considerable quantity of a matter analogous to coagulated albumen, and might, therefore, be advantageously employed as Manure.

We include under the head of Animal Manures such as are strictly excrementitious, and which, if reference were made to their origin, might be regarded as rather belonging to the class of vegetable substances. Besides the dung collected in stables and cow-houses, great attention is paid in some parts to that produced by sheep. In certain districts on the Continent, these last are kept under cover all the year, for the [illegible] Manure which is thereby created; and when they graze along the sides of roads, young children are employed to collect their droppings. Sheep fed on linseed cake produce an extraordinary fertilizing dung, by which any poor land, whether arable or pasture, may be speedily enriched. A plan has lately been adopted of folding sheep upon straw in the corner of a turnip field, and of carrying their food to them; a method particularly suited for such lands as are too wet and tenacious to have the turnips eaten upon them, or for sloping grounds whence the Manure might be washed down. The dung of birds has likewise been held in high importance by the practical farmer, and especially of those species which live upon fish. This substance is produced in so great quantities upon some small islands in the South Sea, that fifty large vessels are annually employed to convey it to Peru, where it is employed to fertilize the extensive plains in the neighbourhood. The dung of sea-birds has not hitherto been much used as a Manure in this Country; though it is probable that even the soil scraped from such of the small islands on our coast as are much frequented by them, would prove very advantageous. An experiment was made under the superintendence of Sir H. Davy, which was attended with great success.

Night-soil, it is well known, as being very liable to decompose, is a powerful Manure. The disagreeable smell may be obviated by mixing it with quick-lime; for if exposed in fine weather to the atmosphere in thin layers, strewed over with that substance, it soon pulverizes, and in this state may be used in the same manner as rape-cake.

Miscellaneous Manures.

5. Under the head of *Miscellaneous Manures* a great variety of putrescent substances might be arranged, but we shall confine ourselves to a short account of the method of forming composts.

Composts,

All Manures may perhaps be considered as compounds; and hence a reasonable question might arise whether the benefits they afford to vegetation would not be increased, were some of the changes which they undergo when mixed with the soil, previously accomplished by means of Art. This question, which is avowedly of great importance, must depend for its solution on a more perfect knowledge of the process of vegetation itself than we yet possess, as well as of those combinations which are affected by the mutual action of the different substances employed by the husbandman to further its progress. As to composts, it may be remarked, in general, that they are formed of almost every kind of animal and vegetable matter, mixed with earthy and saline ingredients, which being thrown together in considerable masses, undergo a certain degree of fermentation, and thereby promote the decomposition of such of them as happen to have been organized.

with lime,

It is a general practice to make a compost with a portion of common Manure or lime mixed with a certain quantity of earth from a ploughed field. In this case the two substances are placed in alternate layers in the form of a lengthened heap or mound, which ought to be so covered at top as to prevent the rain from washing through it, and thereby checking the process of fermentation. When the decomposition is completed, the mass should be

Agriculture. carefully turned, in order that the ingredients may be perfectly mixed together. The quantity may be increased by collecting weeds or other soluble matter from the ditches and hedges in the neighbourhood, and adding them to the heap before the warmth has entirely subsided. When lime is used, it is customary to lay it down fresh from the kiln in given quantities along the end of a field, and to cover it with four or five times its bulk of pulverized earth, which is immediately beaten down with a shovel to prevent the approach of rain or air. The lime is slaked in a few days by the moisture of the soil, and when any cracks or fissures appear, they ought to be covered up with more earth. After a short period, the two substances are completely incorporated, and the compound may be used for grass or corn-crops, either singly, or together with dung from the stable yard, the consistence of which it materially improves.

with peat-moss.

There is no compost better known in most parts of the Kingdom than that of which peat-moss is the principal ingredient. As this substance consists chiefly of vegetable matter, it constitutes, when entirely decomposed, a very valuable Manure. The best authority on this subject is Lord Meadowbank, one of the Scottish Judges, who about thirty years ago published some important notices respecting the method of preparation, and the soils to which it is most beneficially applied. The peat, of which the compost is to be formed, should be dug out some weeks before it is used, in order that the redundant moisture may evaporate. When carried to a convenient place, it is laid out in two rows, with an intermediate row of dung, which should be so near as to allow a workman to throw them together with his spade. A layer of peat six inches deep and 15 feet wide is first formed. A layer of ten inches of dung next succeeds, then six inches of peat, then four or five of dung, and then six more of peat, and a thin layer of dung. Then cover it with peat all round and above. The height should not exceed $4\frac{1}{2}$ feet, otherwise the weight may be too great, and check the decomposition.

In a medium temperature of the atmosphere, seven cart loads of stable-yard dung, in a fresh state, are esteemed sufficient for twenty-one loads of moss; but in cold weather a larger proportion of dung is required, because more heat is necessary to secure a prosperous result. To every twenty-eight carts of the compost it is beneficial to add one load of ashes, whether from coal, peat, or wood; and when such ashes cannot be procured, half the quantity of slaked lime, well powdered, is a good substitute. By employing the refuse of shambles, six times the quantity of moss may be converted into Manure. A similar proportion is obtained from the dung of pigeons and of domestic fowls.

When the compost is made up, the temperature increases according to the state of the weather and the condition of the ingredients. In Summer the moss is heated in about ten days, but in Winter, if the cold be severe, it requires as many weeks. In the former season there is danger that the temperature shall rise too high and consume the materials. When this is apprehended, a stick should be kept in different parts of the mass, which being occasionally examined will indicate the varying degree of heat. When it exceeds 180° the heap should be watered, or turned over, and cooled by an addition of fresh moss. After the process is completed, the whole appears like a black, rich mould, and has been found, when used either for corn or pasture lands, to be equal to the same bulk of good farm-yard dung. The quantity applied must, of course, be regulated by the nature and condition of the soil; but the farmer will receive an ample remuneration for thirty or thirty-five loads per acre.

It is properly stated by the writer to whom we have referred, that too much attention cannot be given to the preparation of the ground to which this compost is to be applied. It should be clean, dry, well mixed, and friable; for in any other state the Manure does not produce its proper effect. The addition of a small quantity of compost has been known to be attended with a wonderful improvement on a field judiciously fallowed. The texture, colour, and other properties of the soil underwent a very perceptible change for the better; a result which must have been occasioned by the mutual action of the different ingredients in the Manure and land, and the new combinations thence proceeding agreeably to the laws of their chemical affinities. It is obvious that this process must be greatly accelerated by bringing the minute particles of both into contact by an intimate mixture.

There is also a compost of peat, lime, and clay, which has been proved to answer well on lands of a certain quality, and more especially for the purpose of raising a plentiful crop of grass. But as we cannot enter into details, we shall finish this section with a short account of some experiments made by the Reverend Mr. Cartwright, with the view of determining the effects of different Manures on the same soil and for the same crop, and particularly of salt used as the means of increasing vegetation. The soil in question was a ferruginous sand, which was brought to a proper consistence by a liberal allowance of pond mud.

Mr C. wright['s] [exp]eri[m]ents.

In the month of April a portion of the field was laid out in beds, a yard wide and forty yards long. Of these twenty-five were treated as follows:

No. 1. No Manure.
2. Salt, one peck and a quarter.
3. Lime, one bushel.
4. Soot, one peck.
5. Wood ashes, two pecks.
6. Sawdust, three bushels.
7. Malt dust, two pecks.
8. Peat, three bushels.
9. Decayed leaves, three bushels.
10. Fresh dung, three bushels.
11. Chandler's greaves, three pounds.
12. Salt, lime.
13. Salt, lime, sulphuric acid.
14. Salt, lime, peat.
15. Salt, lime, dung.
16. Salt, lime, gypsum, peat.
17. Salt, soot.
18. Salt, wood ashes.
19. Salt, sawdust.
20. Salt, malt dust.
21. Salt, peat.
22. Salt, peat, bone dust.
23. Salt, decayed leaves.
24. Salt, peat ashes.
25. Salt, chandler's greaves.

The quantity of each ingredient was the same as when they were used singly. On the same day one row of potatoes was planted in each bed; and that the experiment might be accurately conducted, the number of sets was the same in all. When the shoots appeared above

Agriculture.

ground, their comparative excellence was carefully noted. The best row, at that period, was No. 7. from malt dust; and the next best was that from chandler's greaves. The most backward, in the Month of May, was No. 6. which had been manured with sawdust. On the 21st September the potatoes were taken up, when the produce of each row was as follows:

No. 17.	Salt and soot, produced	240
11.	Chandler's greaves	220
18.	Salt, wood ashes	217
16.	Salt, gypsum, peat, lime	199
15.	Salt, lime, dung	198
3.	Salt	195
25.	Salt, greaves	193
4.	Soot	192
10.	Fresh dung	192
20.	Salt, malt dust	189
5.	Wood ashes	187
23.	Salt, decayed leaves	187
24.	Salt, peat ashes	185
7.	Malt-dust	184
14.	Salt, lime, peat	183
19.	Salt, sawdust	180
22.	Salt, peat, bone dust	178
9.	Decayed leaves	175
13.	Salt, lime, sulphuric acid	175
21.	Salt, peat	171
8.	Peat	169
12.	Salt, lime	167
1.	No Manure	157
6.	Sawdust	155
2.	Lime	150

Efficacy of salt

It is remarked by the author of these experiments as a singular circumstance, that of ten different Manures, most of which are of acknowledged efficacy, salt, the effects of which were doubtful, is, with one exception, superior to them all; while in combination with other substances none except chandler's greaves was injured by it. The energy of salt when combined with soot was very striking. But Mr. Cartwright was disposed to ascribe its effects rather to the power which it possesses of attracting moisture from the atmosphere than to any chemical action between the two substances; for the beds on which the salt was used continued visibly moister than the others, even for weeks after its application. Another circumstance noticed is, that the plants which grew on the beds Manured with salt, were of a paler green than the rest, but equally luxuriant; which appearance he at first regarded as an indication of want of vigour, an opinion by no means confirmed by the result. He found, too, that wherever salt was applied, either by itself or in combination with other substances, the roots were perfectly clean.

Experiments with turnips and buck-wheat.

The same gentleman instituted two sets of experiments with turnips and buck-wheat, on a soil so poor as to produce only dwarf heath and lichen. Of 400 grains, 320 consisted of silicious sand, 68 of finely divided matter, and 12 of moisture. Scarcely any calcareous matter appeared. On the 6th of July the beds selected for each set of experiments were respectively sown with turnip and buck-wheat; being numbered and Manured exactly in the same way as in the first set of experiments with potatoes. On the 20th of July Nos. 1, 2. 4, 5, 6, 7. 19, 20, 21, 22. 24, 25. showed little or no marks of vegetation; the remainder were merely in the seed leaf. On the 16th of August four only were alive and in rough leaf, namely,

No. 12. Salt and lime.
13. Salt, lime, and sulphuric acid.
14. Salt, lime, peat.
16. Salt, lime, gypsum, peat.

Results.

These four continued in a sickly state till the middle of September, soon after which they disappeared. The fate of the turnip and buck-wheat was nearly the same; but no certain conclusion could be drawn from these experiments with regard to the effects of salt as a Manure for such crops, for other Manures of undoubted efficacy also failed. The proper inference to be deduced from the whole is, that a certain texture and composition of soil is an essential requisite for promoting the health and vigour of plants, which was abundantly obvious in the greater luxuriance of those plants where the Manure acted in some degree as a substitute for the natural qualities of the land. It has been justly remarked, that these experiments may serve as a model to such Agriculturists as have leisure or inclination to investigate the effects of different kinds of Manure on the crops to which they are applied; and although many of them were made on substances which are procured with difficulty, or are to be had only in small quantities, and cannot therefore come into general use, yet the results obtained were curious and interesting, and, if further examined, might lead to the discovery of some valuable principles as to the constitution and improvement of soils.

Project for employing diluted sulphuric Acid on peat-moss.

While writing this portion of our Essay we have received a faint notice of a scheme for fertilizing peat-moss by means of sulphuric Acid considerably diluted. The project originated somewhere in Germany, whence it was carried into Russia, and reduced to practice it is said with some appearance of success. From the North of Europe it found its way into Ireland, where it has been tried by several Agriculturists, who have experienced much advantage from it in the improvement of their bogs. It has been recently introduced into the Western parts of Scotland, where the soil bears some resemblance to that on the opposite side of St. George's Channel; but the details which have reached us are neither sufficiently ample, nor so accurately described, as to justify any opinion as to its ultimate effects.

Desiderata in Manures.

The farmer and landowner have long had their attention directed to the subject of Manures, as the only source whence any material discovery can be derived to aid their exertions in the production of food. Much has been done by the Mechanic in inventing and improving Agricultural instruments; but the labours of the Chemist have not yet, in any essential point, increased the resources of the husbandman. Manures, generally speaking, are still as bulky, weighty, and expensive as they were fifty years ago; and hence the disheartening fact that they must be used at no great distance from the place at which they are produced, while lands further removed are doomed to continue sterile and unproductive. The desideratum on which practical men have now everywhere fixed their thoughts is the discovery of a substance, so limited in volume and weight as to be easily conveyed from one district to another—an essence, in short, or condensed principle of fertilization, the carriage of which will not, like that of our common Manures, exceed the cost of purchase. It may, perhaps, be found in some one of the Acids or

Agriculture. Alkalis, which in a highly concentrated state might be sent to a distance at small expense; on which account we are the more anxious to become acquainted with the experiments mentioned in the last paragraph, in regard to the fertilizing properties of the oil of vitriol.

Implements of Husbandry.

We have already mentioned the great obligations under which the pursuits of husbandry are placed to the ingenuity of our artisans. The inventions of the Mechanic have not unfrequently anticipated the wants of the Agriculturist; and at this moment, accordingly, all the nations of Europe look to this Country for whatever progress is expected in the formation of new instruments, or in the improvement of the old. Such tools have usually been classed by systematic writers according to their use, or the purposes for which they are employed; and hence they may be arranged as they respect ploughing, sowing, weeding, reaping, and threshing; or, in other words, as they facilitate the rearing of the crop and the preparation of it for the market, in which the interest of the farmer in the produce of his land has its natural termination.

Classification.

Under the head AGRICULTURAL IMPLEMENTS in our *Miscellaneous Division*, we have already described the chief varieties of *Ploughs* and *Harrows*, the *Scarifier*, the *Scuffler*, and the *Roll*.

Machines for sowing.

Various instruments have been used from time to time for sowing corn, and more especially turnips, to supersede the clumsy and wasteful method of scattering the seed with the hand. It is certainly desirable that every species of seed should be sown in a regular manner and at a proper depth. In the East Indies machines for that purpose have been employed for Ages; but their introduction into Europe is comparatively speaking of recent date, and is principally to be attributed to the exertions of the celebrated Tull.

Drill machines.

The *Drill machine* for sowing turnip-seed, says Sir John Sinclair, cannot be too much recommended; for it has been the means of bringing the culture of that plant to the highest state of perfection. An excellent instrument for drilling peas and beans likewise has been constructed. In regard to drills for the several sorts of grain, a great diversity of opinion prevails. It seems to be admitted, however, where wheat, barley, or oats are sown in Spring, that, for the purpose of extirpating annual weeds, the drilling system is to be preferred; but in regard to Autumnal or Winter-sown wheat, where the land has been fallowed, the broad-cast system may be advantageously adopted.

Drill-furrow.

Some objections to the practice of drilling corn have been removed by the recent invention of a Drill-furrow, which, though peculiarly well calculated for small farms, might likewise be used with benefit on large ones. It is very simple and may be employed in either of two ways; as a box or barrow attached to the Plough, by which the seed is deposited in the furrow, or in the hands of a boy who follows the Plough for the same purpose. The advantages of this machine are; 1. that the seed being dropped at a proper depth takes a fast hold of the ground, and is not affected by the Winter's frost; 2. the seed may be deposited by means of it in windy weather, when broad-cast sowing would be attended with difficulty; 3. any weeds growing between the rows can be completely extirpated; and 4. there is no way in which clover can be sown with Winter wheat, in the Spring, to greater advantage, as the intervals between the drills can be suitably hoed and the seed laid on a clean bed.

Reaping machine.

But of all the apparatus recommended to the Agriculturist there is not one of greater importance to him than the *Reaping machine*, which however has not yet been brought to such a degree of perfection as to be entitled to general use. The first attempt of this kind is said to have been made by Mr. Boyce, who about thirty years ago obtained a patent for his invention. His instrument was placed in a two-wheeled carriage bearing some resemblance to a cart, but the wheels being fixed upon the axle the latter revolved along with them. A cog-wheel within the carriage turned a smaller one at the upper end of an inclined axis, and at the lower end of this was a larger wheel which gave a rapid motion to a pinion fixed upon a vertical axis in the fore-part of the carriage and rather on one side, so that it went before one of the wheels. The vertical spindle descended to within a few inches of the surface of the ground, and had there a number of scythes fixed upon it horizontally. The machine when wheeled along cut down by the rapid revolution of its scythes a large quantity of corn; but not being provided with any apparatus for gathering it up in parcels and laying it in proper heaps, it proved wholly unfit for the purpose intended.

Invented by Mr. Boyce.

Mr. Plucknet of London attempted to improve it, but without directing his attention to its main defect. He substituted for the scythes a circular steel plate, made very sharp at the edge, and notched on the upper side like a sickle. This plate operated in the same manner as a very fine toothed saw, and was found to cut the corn much better than the implements of Mr. Boyce. But neither by this method was the principal objection removed.

Improved by Mr. Plucknet,

Mr. Salmon of Bedfordshire made a nearer approach than any of his predecessors towards supplying the desideratum so much felt by the Agricultural community. His machine was constructed upon totally different principles, as it cut the corn by means of shears instead of a circular plate; and it was provided besides with a complete apparatus for laying it down in parcels as it was cut.

by Mr. Salmon,

But a still more successful effort was made by Mr. Smith, in the County of Perth, who, about twenty years ago, contrived an implement for reaping which might be worked by two men. He afterwards repeatedly enlarged the scale till it required the power of two horses; and at the same time removed an obstacle which applied to the action of his machine on an uneven surface. Suffice it to observe that his cutter is circular and operates horizontally. It is appended to a drum connected with the fore part of the structure, and has its blade projecting some inches beyond the circumference of the lower end of the drum; the machine being so contrived as to communicate, in moving forward, a rapid rotatory motion to this drum and cutter, by which the stalks are cut, and falling upon the drum are carried round and thrown off in regular rows. This ingenious piece of machinery will reap about an acre in the hour, during which period the cutter requires to be three or four times sharpened. The delay occasioned by this necessity might perhaps be obviated on the principle adopted by Mr. Gladstones, who attached to the Plucknet implement a small wooden wheel covered with emery, which being always in contact with the great

by Mr. Smith,

Agriculture. cutter at the back part, or opposite side to that where the operation of cutting was performed, kept it constantly ground to a sharp edge. The expense of Mr. Smith's invention is estimated at from £25 to £35; and if properly managed it will last for many years, requiring only a new cutter at certain intervals. But notwithstanding the most promising appearances, it is doubtful whether the practical farmer is yet inspired with sufficient confidence in its fitness for all sorts of work, to afford the encouragement necessary to bring it into general use. Fig. 23.

by Mr. Bell. We have to mention another attempt of this nature made by the Reverend Mr. Bell, a gentleman distinguished for considerable scientific attainments. His machine was tried at Powrie, in the County of Forfar, about three years ago, in cutting down oats, barley, and wheat, on ground of uneven surface and considerable declivity. It takes in a range of about five feet; cutting within three or four inches of the root; and depositing the grain, as it advances, in a very regular manner. It is worked by one horse, and clears about an imperial acre per hour. Its cost may be calculated at nearly £30. In the opinion of a skilful Agriculturist who witnessed the trial of its powers, it is better fitted than any other to supersede the sickle, and thereby to confer a general benefit on the occupiers of land. Fig. 24.

Hainault scythe. As the process of reaping in our variable climate is attended with many interruptions and much expense, no means have been left untried for facilitating the operation. The *Hainault scythe* had long been recommended as a better implement for this purpose than the sickle or scythe in common use; for which reason two young men were brought over from Flanders under the sanction of the French Consul at Edinburgh, to afford a practical demonstration of the superiority of their instrument, and, at the same time, to instruct the British labourers in the use of it. The trials were made, after public notice in several parts of Scotland, with the different varieties of grain, and under different circumstances as to the state of the crop, as to being light or heavy, standing or laid; and the results are said to have been very much in its favour. The straw was cut nearly as close as with the common scythe, taken up clean, except where the crop was very thin, and laid down regularly in the proper state for binding and threshing. A man with this tool will cut about half an acre a day; and the consequent saving compared with the common sickle has been calculated at fully one third. Fig. 25 and 26.

Horse Rake. Wherever corn is cut with the scythe the *Horse Rake* is found a useful implement for saving manual labour, as it must also be in the process of making hay. A model was recently brought from America by a gentleman who had visited the United States, and the instrument itself is now generally used in certain districts of Great Britain. The teeth are of iron, 14 or 15 inches in length, and set five or six inches apart from each other; and on the whole, the construction is very simple. A man and horse are said to be able to clear from 20 to 30 acres in a day, disposing the grain in lines across the field, by lifting up the rake and dropping it from the teeth without stopping the horse. We have no doubt that it will be extensively introduced into all parts of the Kingdom as a very useful invention. Fig. 27.

Threshing machine. Among Agricultural implements no one is entitled to higher commendation for its various uses than that which is employed for *Threshing* and clearing corn. The saving of labour by means of this invention is very great while the work is in all respects better done. Nothing could be more barbarous than the mode adopted by some of the Ancients of separating the grain from the straw, either by burning the latter, or by treading the whole under the feet of oxen. Even the Flail was a very imperfect and fatiguing instrument. Threshing-machines are now common everywhere, and may, it is well known, be worked by horses or water, wind or steam. Water is by far the best power, but as a full supply cannot at all times be had, horses are still employed more generally than any of the other motive energies.

The essential parts of the machine will be fully understood from an inspection of the engraving. Among the various modifications which are occasionally introduced, one of the most useful is what is called the *Travelling Shaker*, the intention of which is to convey the straw, after it is separated from the corn, to the straw-barn, shaking it completely as it goes along. All well-constructed Threshing-mills have one Winnowing machine which separates the chaff from the corn before it reaches the ground; and a second sometimes receives it from the first, and gives it out in a state nearly ready for market at the rate of six or eight quarters in the hour. If the dimensions of the building do not admit of this last addition, a separate Winnowing machine is sometimes moved by a belt connected with the mill; saving in either case a great amount of manual labour. With a powerful water-mill it cannot be doubted that corn is threshed and dressed for the market at an expense not exceeding that which was incurred by the old process for threshing alone. The great advantage, too, of transferring forty or fifty quarters of grain in a few hours, and under the eye of the master, from the yard to the granary, is of itself sufficient to recommend this invaluable machine, even though it were not also more economical. Fig. 28. Travelling Shaker.

The author of the *Treatise on Rural Affairs* has furnished the following estimate of the profit that might be derived by the Public were Threshing-mills universally adopted. He calculates,

1. The number of acres producing grain in Britain at	8,000,000
2. The average produce in quarters at three per acre	24,000,000
3. The increased quantity of grain obtained by Threshing-mills, compared with the Flail, at one-twentieth of the whole, or in quarters at	1,200,000
4. The value of that increased quantity at forty shillings per quarter	2,400,000
5. The saving in expense of labour at one shilling per quarter	1,200,000
6. The total profit *per annum*, if all were threshed by machinery, at	3,600,000
7. The actual profit *per annum*, on the supposition that only half of the grain produced were threshed by machines, at	1,800,000

Miscellaneous Implements. In addition to the implements already described we might mention the *Chaff-cutter*, the *Turnip-sheer*, the *Steaming apparatus for preparing the food of cattle*, and a *Machine for bruising the corn which is given to horses*. This last is of greater value than it is usually imagined, as many horses are known to swallow their oats without complete mastication, while others which have lost their teeth derive much advantage from this artificial assist-

Agriculture.

ance. We must pass over with a similar brevity the various descriptions of wheel-carriages which are used on farms, from the Irish car to the Gloucestershire waggon. There are besides various mechanical inventions used for harvesting corn, and depositing it safely in the barn yard. Sir J. Sinclair holds the opinion that stacks are greatly preferable to barns, more especially since the plan has been adopted of placing the former on stone or cast-iron pillars, by which the corn is kept perfectly dry, and the ravages of vermin are prevented. In some districts, if the season be wet, stacks have *bosses* placed in the centre, consisting of a triangle of wood, through which the air has freedom to circulate nearly to the top of the stack. If the grain has not been quite dry, it gains much advantage from this simple expedient. Fig. 29.

Bosses for corn stacks

On Tillage.

Having examined the constitution of soils, the modes of draining and irrigation, the various kinds of manure, and the principal implements which are used in husbandry, we are now prepared to accompany the farmer in the more practical branches of his profession, and to record his progress in the culture of his fields and the growing of his crops. It is, indeed, customary before proceeding to the actual processes of ploughing, sowing, and reaping, to make a series of observations on the different plans which have been adopted in the Agricultural districts of the Kingdom, for dividing fields and erecting fences. To this is not unfrequently added a dissertation on rural establishments, comprehending a view of the several buildings which may be thought necessary to accommodate the tenant, his servants, his cattle, as well as his pigs and poultry, and, at the same time, supply the means of protecting his crop, his corn, potatoes, turnips, and hay, from the effects of rain and frost. We abstain from such details, not only because our plan is inconsistent with excessive minuteness, but more especially because there is no fixed rule which could be made to apply to any number of contiguous farms, much less to the whole country. The fences which are found most suitable in Devonshire would not answer in Cumberland; and the style of house which affords the greatest comfort in Caithness, would be rejected on the banks of the Severn and the Thames, as inconvenient and devoid of elegance.

Turning up the soil.

The first step is to turn up the soil and prepare it for the reception of the seed. But before the operation of the plough begins, it is of no small importance to consider the nature of the land, the season of the year, and the species of crop which it is proposed to raise. It is a general opinion that there are few soils which are not improved by being turned up about the end of Autumn or beginning of Winter, as it is understood that they thereby absorb a great quantity of moisture to meet the demands of the following Summer; whereas, if they are not ploughed till the Spring, the rapid evaporation which ensues occasions a deficiency of one of the essential elements of vegetable life. It is supposed, too, that the furrow exposed during the cold season becomes mellow, and derives, moreover, some beneficial influence from the atmosphere; an opinion which may be traced back to the days of Virgil, and perhaps to an epoch still more ancient. But the experience of modern times does not altogether confirm the judgment of the Greeks and Romans in this particular point. The principal benefit of Autumnal ploughing is confined to strong adhesive soils, which by means of the frost acting on the redundant moisture, unquestionably renders them more friable, and, of course, fitter for the reception of all kinds of seed.

Fittest season.

Ground not to be ploughed when wet

It ought to be especially observed that no land, whatever may be its qualities, should be ploughed in a state of wetness. Tenacious soils, when subjected to the operation of ploughing in such a condition, are apt to run together into lumps, which it is afterwards extremely difficult to reduce; besides being greatly injured by the treading of the cattle, whose feet make holes which become filled with putrid water. This observation applies chiefly to marshy fields, which have been recently brought into cultivation, and which, above all others, ought not to be endangered by an unseasonable renewal of Tillage.

Dimensions of the furrow

In highly improved districts, great attention is paid to the dimensions of the furrow, and the angle at which it is made to rest. When the breadth and depth are nearly equal, it turns over very naturally at an angle of forty-five degrees; but when the breadth much exceeds the depth, it falls over in nearly a flat position, each successive one overlapping a little the preceding. The nature and condition of the land determine the preference to be given to each of these modes of ploughing. The square slice is considered best adapted for laying up stubble land after harvest, to be exposed during the Winter as a preparation for fallow or turnips. The shallow slice with considerable breadth is convenient for breaking up old pastures, because while it conceals the grassy turf, the fertile soil is not buried too deep. No wise farmer approves that style of aration which makes the depth of the furrow slice exceed the breadth.

Considerations by which they are determined.

Generally speaking, in determining the depth of the furrow, the quality of the soil, and the kind of crop to be raised, must be attentively considered. Some shallow soils are extremely fertile, but rest on a substratum which is extremely injurious to vegetation. In such cases, deep ploughing would be highly improper; but, on the other hand, when subsoil contains ingredients, such as calcareous and soluble matter, which serve to increase its productive qualities, it may be useful to the crop to have a portion of them occasionally turned up by the plough. Mr. Young recommends that one deep ploughing should be given every second year; after which, he maintains, that a mere stirring of the surface answers better than very deep working. Even for the purposes of cleaning, it is found that an ebb furrow, followed by regular hand-hoeing is much more effectual than any attempt to bury the weeds.

Deep ploughing where necessary.

For certain crops, indeed, such as carrots and parsnips, deep ploughing is indispensably requisite. In soils which can admit of it, *trench-ploughing* is found advantageous; a process which is accomplished by one plough following another in the same furrow, and the second throwing its slice on the top of that which has been turned over by the first. In this way the land is completely moved to the depth of twelve or thirteen inches.

Ridges.

In ploughing a field some attention ought to be paid to the breadth of the ridges, or the distance of the water-furrows from each other; for upon this arrangement depends not only the proper draining of the surface, but also the regular application of manure, the equal distribution of the seed, the weeding, reaping, and other branches of manual labour. It is likewise recommended by experienced farmers that as far as the situation of a field will admit of it, the direction of the ridges

Their direction

Agriculture. should be North and South. Deviations from this rule, for the purpose of drainage, or on account of the particular form of an inclosure, may be sometimes necessary. But it seems always advantageous to bring the course of the ridges as near as possible to the line abovementioned; for it appears that in those which have an East and Westerly direction, even when the elevation is not considerable, the crop on the South side has ripened a week earlier than that on the North.

and breadth.

Great diversity of opinion prevails as to the proper breadth of ridges; a point which, it is manifest, depends altogether on the qualities of the soil. Where the land is of a light sandy nature, the ridges may with perfect safety be made both flat and broad; whereas on a stiff clay, they should be more narrow as well as higher and of a rounded form, that the redundant moisture may be discharged. On some such soils a ridge of three or four feet is considered sufficiently wide; and in Essex, especially, this method is found to yield better crops than when the water-furrows are placed at more distant intervals. But as we have already suggested, there is no uniformity in this particular, the practice being regulated in every County by the properties which distinguish the various farms, as also by the uses to which the land is applied.

Fallowing.

There is no subject connected with Agriculture on which there has been a greater change of practice as well as of theory, than the ancient usage of Fallowing. A vague notion seems to have prevailed in all the Countries of Europe that the exhausted soil required some time for repose, in order to recover its wasted fertility. At the present day many authors maintain that, under good management, and a proper succession of crops, it is hardly ever necessary for most kinds of land; while others with equal confidence assert, that Summer Fallowing forms an essential part of a system of good husbandry, and that on certain soils it is altogether indispensable. The avowed object of this process is, to clear the ground from weeds, and to reduce it to that consistence which is necessary to healthy vegetation. The more zealous advocates of the practice admit, though with reluctance, that it may be restricted to clay soils, and to those which are of a tenacious quality; such being apt to retain a superabundance of moisture, and to be thereby rendered very often unfit for receiving cultivation at the usual season. Ploughing in Summer, they remind us, reduces the hardened mould to the degree of friability and minuteness of division which are essential to the concoction of the manure, to the approach of the genial atmospheric influences, and to the ready nourishment of the plants. The soil from being brought repeatedly in contact with the air is supplied with a larger proportion of oxygen, which uniting with the carbonaceous matter deposited by the husbandman, produces an acid extremely beneficial to all the vegetable tribes. According to the same hypothetical reasoning, the water which is absorbed by the pulverized field is decomposed, and its hydrogen combining with the azote of the air forms ammonia, while another portion of oxygen uniting with part of the nitrogen furnishes one of the ingredients of potash, and thereby contributes greatly to the improvement of the land. Certain vicissitudes of temperature, too, which, no doubt, take place wherever any decomposition or Chemical change in the constituent parts of bodies is effected, are also supposed to be useful, either directly or indirectly, in promoting the growth of plants.

Agriculture.

Sir H. Davy's objections to Fallowing.

But as Sir H. Davy observes, there is some reason to suspect that the benefits derived from Fallowing have been greatly overrated; and although it may be admitted as necessary in lands much infested with weeds, and particularly on such as cannot be pared and burned with advantage, it must nevertheless, on the whole, be pronounced unprofitable as a part of general husbandry. He rejects the doctrine that certain principles necessary to fertility are derived from the atmosphere, and supplied to the pulverized soil, during its repose and repeated exposure to the air; as well as the old opinion as to the effects of nitrous salts on vegetation. By the decomposition of the weeds buried under the furrow a certain quantity of soluble matter is no doubt furnished to the land; but it may be questioned whether the portion of useful manure in a field at the end of a clear fallow, is equal to what it contained when the operation commenced. By the action of the vegetable matter on the oxygen of the atmosphere carbonic Acid gas is formed; but the greater part of it is dissipated and lost to the farmer. The rapidity of the decomposition of the soluble substances contained in the soil is greatly promoted, and the volatile fluids are exhaled by the influence of the Sun; but at the very time when a large quantity of nutritious matter is produced there are no useful plants to derive any benefit from it.

His general remarks.

The whole theory of Fallowing, if we omit the mere eradication of weeds, rests on the principle that land, while not employed in raising a regular crop, may be so treated as to supply food for itself, or, in other words, to improve its productive qualities. This object, as we have elsewhere stated, may be in a great measure accomplished by means of succulent vegetables grown for the purpose of being ploughed down. But during a Summer fallow, properly so called, no crop is produced either for food to animals or for the nourishment of the soil itself. Even the texture of the furrow is less improved than during its exposure in Winter, when the freezing of the moisture it contains has the effect of reducing it to a gentle condition. Besides, since the drill-husbandry has been introduced the land is kept free from weeds by hand-hoeing, and manure is supplied either by the green crops themselves, or from the dung of the animals which feed upon them. It is the peculiar advantage of the convertible system of cultivation that the whole of the manure is employed; those parts of it which are less fitted for one crop being suitable for the nourishment of another. Thus the quantity applied to turnips affords a sufficient portion of soluble matter not only for their growth, but also for that of the barley which follows in the regular succession of modern husbandry. Nay the grass-seeds derive from the same supply an abundant source of luxuriance, while the rye-grass and clover remain, which draw a very small part of their organized matter from the soil, or only consume the gypsum, a mineral ingredient of little use to other plants. These grasses are supposed to receive a large portion of their nourishment from the atmosphere, and their roots and leaves when ploughed down at the end of two years, supply a pabulum to the succeeding wheat crop. At this stage of the course the farm-yard manure, which contains phosphate of lime and other matters of difficult solubility, is fully decomposed; and as soon as the most exhausting crop is raised the application of similar substances is repeated.

Mr. Gregg's system.

These remarks were suggested to Sir H. Davy by considering Mr. Coke's plan of cultivation independent

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of Summer Fallowing. Mr. Gregg, whose ingenious system was published by the Board of Agriculture, had the merit of first adopting a similar plan on strong clays. He allows the ground after barley to remain two years in grass; then sows peas and beans; afterwards ploughs in the stubble of these crops for wheat; and, in some instances, fallows the wheat by a course of Winter tares and barley, which is cut in the Spring before the land is sowed with turnips.

Mr. Middleton's observations.

There can be no doubt that were it possible to devise any method of cropping by which the produce, fertility, and good condition of the soil could be maintained without the intervention of a Summer Fallow, the saving would be very great. Mr. Middleton accordingly, in his *Report of the State of Agriculture in Middlesex*, when speaking of the advantages to be gained by a proper succession of crops, very justly remarks, that the "benefits to be derived from this measure are not to be estimated. Among the first of these will stand the abolition of Fallows, and the introduction of green crops to supply their place, over an extent of about three millions of acres of arable land which have hitherto, under the Fallow system, produced nothing during the Fallow year. So far as tares and turnips, or potatoes and pease, or turnips and potatoes, or any two good crops can be raised in one year, in place of a Fallow, the produce will be double in quantity what it has been under the former system. There are about nine millions of acres in England and Wales in the course of two crops and a Fallow; that is, six in crop and three in Fallow; from which it appears that by procuring one crop in place of the Fallow, one half more is added to the former produce."

Fallows disused in the Netherlands,

According to a statement made by Sir John Sinclair, in his *Hints on the Agricultural State of the Netherlands*, Fallows are more rarely practised in Flanders than formerly, and in some districts are entirely abolished. The succession of crops on strong lands in the neighbourhood of Bruges is the following; Fallow, winter barley, beans, wheat, oats: sometimes there is a Fallow every fourth year, and sometimes wheat and Fallow alternate. But in the Plain of Fleurus, in the Walloon Country, Fallows are now rarely seen. At one period they were enforced by a clause in the leases as an indispensable part of husbandry in that fertile district. M. Mondez, who was well acquainted with Flemish farming, when he entered on the possession of grounds near the town just named, having stipulated with his landlord that he should be at liberty to pursue a different plan of cultivation, took the lead in this great improvement; and for a period of forty years he seldom had occasion to practise Summer Fallow. He superseded the old method by introducing a judicious rotation of crops. The culture of beans, for example, is successfully practised in other parts instead of a Fallow. This crop is succeeded by an abundant one of wheat or Winter barley; and it is added by Sir John, "that this system merits to be encouraged for the great advantage derived from it; for without any additional manure, which however it tends to furnish, it retains the fields in as high a state of fertility as can be done by the Fallow system; it exacts but a moderate degree of attention, and it requires neither any extraordinary expense nor hazardous combinations."

The same author informs us, that it is now a maxim in the Plain of Fleurus that, wherever it is possible to manure the land fully every ninth year, Fallows are perfectly unnecessary; and he notices a Paper on this subject by M. Burtin of Brussels, who recommends mixing sand with the soil, to alter and improve its texture, and burning clay in large masses for the same purpose, as a substitute for Summer ploughing. At one time, we may remark, Fallowing was so much practised in Swisserland that it alternated with every crop; but at present it is almost entirely given up, the necessity for it being precluded by the following rotation, wheat, carrots, vetches, barley, potatoes.

and in Swisserland.

Norfolk Bastard summer till.

In Norfolk a kind of Fallow, denominated by the farmers a *Bastard summer till*, is occasionally practised. If it shall appear that a piece of ground from which clover or some other cultivated grass has been cut, is not sufficiently clear for the reception of the following wheat crop, it is ploughed two or three times, if it can be accomplished, before harvest; and, when it is necessary, the assiduous application of the roller and harrows is not neglected. For the purpose of clearing peastubble, it is also subjected to a similar operation. When the crop is removed from the land, the straw is harrowed up, collected, and carried away. A single ploughing is then given; after which the ground remains in that state till the conclusion of the harvest, when it receives two cross ploughings, and finally, a fourth as a preparation for the seed.

Drill sowing.

As the improvement now mentioned has arisen chiefly from the introduction of green crops cultivated on the plan of what is called the *Drill Husbandry*, we shall make a few observations on its history and advantages.

Introduced by Mr. Tull.

It has been already stated, that this method was introduced into Britain by Mr. Jethro Tull, a gentleman in Berkshire, who applied it to his own property about the year 1713. Struck with the remarkable effects which the new mode produced, and ascribing the abundant crops which he obtained to the perfect culture thereby accomplished, rather than to the fertilizing qualities of the manure, he extolled the discovery beyond all bounds. He described it as calculated to supersede the necessity of manure altogether, the application of which he viewed as a waste of time, labour, and expense. By thus overrating the advantages of Drilling, and loading it with erroneous views on points not necessarily connected with it, there is reason to believe that he retarded the progress of his favourite system. In the present day when the utility of manure is so well understood, there is no danger that any one will be misled by the opinions of Mr. Tull; and we enjoy accordingly all the benefit of his practice without incurring the hazard of his hypothetical conclusions. It required the enthusiasm of an inventor to warm the head to such an extent as to induce a practical Agriculturist to overlook the necessity of recruiting the energies of the soil, or to imagine that the best directed labour would ever supersede the application of manure.

His mistakes.

Advantages.

The main advantages derived from the practice of Drilling are understood to be, a saving of seed; a more regular and certain growth, from the seed being more regularly deposited; a more abundant crop and of a better quality; the more easy and effectual destruction of weeds; harvesting the crop at less expense and in a cleaner state; and the more perfect cultivation of the soil by means whereof it is left in a better condition for the next sowing. The objections to it apply not to the

Objections.

Agriculture.

Mr. Amos's experiments.

process itself but to the difficulty of having it well performed, and the bad effects which result from awkward workmanship. But the experiments made by Mr. Amos, detailed at length in his *Treatise on Drill Husbandry*, have removed all doubt as to the superior excellence of this method. His investigations were made on different soils; and in all of them, two acres of land, laid up in ridges of eleven feet broad, were sown alternately broad-cast, and with the Drill machine. We may state one or two of the results; observing that the sum placed opposite to the name of the crop denotes the superior value of that which was Drilled compared with the produce of the broad-cast.

	£.	s.	d.
Oats on stiff loam	1	3	0
Coleseed after the oats	0	1	0
Barley after the coleseed	1	5	3
Beans after the barley	1	1	3
Wheat after the beans	1	14	5
Turnips on sandy loam	0	8	9
Barley after the turnips	0	17	10
Red clover after the barley	0	10	6
Wheat after the red clover	1	9	9
Potatoes on sandy loam, part hand-hoed, and part horse-hoed, in favour of the latter	3	13	10
Barley after the potatoes	1	16	2
Red clover after the barley	0	13	6
Wheat after the red clover	1	16	0
Cabbages on stiff loam, part hand-hoed and part horse-hoed, in favour of the latter	2	10	9

We ourselves have witnessed experiments on the comparative advantages of Drilling and broad-cast, in regard particularly to wheat and oats; and the result in all cases has tended to prove the decided superiority of the former. Not only is the quantity greater, but the quality is considerably better; and if the season has been wet or otherwise unfavourable, the latter point of improvement is still more manifest. It deserves to be remarked, however, that the saving of seed is quite illusory, for the best farmers bestow as much on the land in the form of Drilling as when it is scattered from the hand. Nor ought it to escape attention that a good deal depends on the distance between the rows or Drills; a branch of the subject which has been well illustrated by Mr. Young, though his conclusions are not entitled to the authority they would have possessed had all the experiments been performed on the same soil and under the same management. Mr. Tull, it is well known, recommended the Drilling of wheat, barley, and other corn crops, at the distance of three, four, and even five feet between the rows; but as this part of his practice was connected with the hypothesis that a well-directed culture might supersede all other means of fertilizing land, he has not been followed, except by a few individuals who were determined to adopt his whole system, and attempt to produce plentiful harvests without the aid of manure. It is obvious that the number of rows in a given space should be regulated by the nature of the soil and the species of the plants; strong land requiring more room for its rank vegetation, and that which is lighter admitting the Drills at a smaller distance from one another. From ten to fourteen inches is recommended as a sufficient interval for rows of corn where the field is in good condition; but in cases where a luxuriant crop is not to be expected, the distance may be reduced with advantage to the narrower limits of eight inches.

No saving in seed.

Intervals between Drills.

Method of Drilling.

The process of Drilling, or the deposition of seed in rows by means of a machine, requires considerable care in the performance. The points which demand particular attention are the keeping the rows straight and at equal distances throughout their whole length, the dropping the seed at a proper depth, and the delivering it in proper quantity according to its kind and the nature of the soil. For these purposes the ground must have been previously well prepared by repeated ploughing and harrowing, except in the special case of Drilling beans with one furrow. This operation is generally performed in the course of ploughing, either by a person pushing forward a Drill barrow, or by attaching a hopper and wheel with the necessary apparatus to the plough itself. The mode of regulating the depth of the Drill, and the quantity of seed delivered, must depend on the kind of Drill used, and only requires attention in the holder. In Drilling turnips the land is most commonly made up into ridgelets, at the distance of twenty-seven or thirty inches from centre to centre, formed by a single *bout*, or double motion, of the common plough. The Northumberland machine, which sows two rows at once, is then drawn over them by one horse walking between the ridges without a driver; the holder at once performing that office and keeping the instrument steady on the top of the Drills, or ridgelets, as they are sometimes called. One of the two rollers smooths the surface before the seed is deposited, and the other follows to cover it and compress the soil. In Drilling corn, several rows are sown at once, and great care is requisite to keep the machine steady and in a straight line. If only five rows are done at once, the work may be performed with one horse and a ploughman, but if the implement is so large as to cover nine or ten rows, there must be two horses in the yoke, and guided by a driver.

Northumberland Drill machine.

For the Northumberland Drilling machine, we refer to fig. 30. The roller *a* which goes before the seed has two concavities, and thus leaves the ridgelets in the very best form for receiving it; after it is sown, two light rollers, *b b*, follow and cover it.

Morton's Drill machine.

Of corn-drills, Morton's *improved grain Drill machine* is undoubtedly the best and simplest. In it three hoppers are included in one box, the seed escaping out of all the three by the revolution of three cylinders upon one axle; and Drills of different breadths are produced by the simple shifting of a nut that fixes a screw moving in a groove in the under frame, by which the distance between the two outside conductors and the central one (which is fixed) can be varied from nine to eleven inches. And in order that the two small wheels may be always at the same distances respectively as the conductors, there are two washers, or hollow cylinders, an inch in breadth, in the axle arms of each, which may be transferred either to the outside or inside of the wheels, so as to make this distance from the outside conductors, nine, ten, or eleven inches respectively. The small wheels may be raised or depressed, so as to alter the depth at which the seed shall be deposited, by the action of a wedge which retains the upright part of the axle in any one of a number of notches, which are made similarly in both, and which are caught by an iron plate on the upper side of the arms which carry the axle. This machine, says Mr. Loudon, may be still further improved by increasing the number of conductors from three to five,

an improvement, we may add, which has already taken place. Fig. 31.

System of Cropping

Modes of classification.

The great variety of soil and climate in this Country suggests and even renders necessary a considerable difference in the kind of crops that must be raised by the farmer, who, in this important matter, is frequently deprived of all power of choice. In a systematic point of view, the produce of land may be considered under such several heads as shall happen to suit the object of the writer; the main distinction being founded on its uses and application, as food for Man, or for the lower animals: the former class comprehends the various species of corn, wheat, barley, rye, oats, peas, and beans; while the latter may be extended to all the vegetable tribes which fall under the denomination of green crops. It is manifest, however, that this distribution does not rest on any fixed principle, because there is none of the *cerealia*, or genera of grasses, from which the human being derives his subsistence, which may not be applied with equal success to the tenants of the stable, the cow-house, and the fold. Perhaps a clearer distinction might be founded on the property of being culmiferous or otherwise, thus dividing the products of land into such as are cultivated for their seeds, and such as are cultivated for their leaves; but as our object is to meet the convenience of the common reader, rather than to comply with the requisitions of a theory not well established, we shall proceed to give an account of those crops which chiefly occupy the attention of the British Agriculturist, and supply the ordinary demand of our markets.

Wheat.

Of these *Wheat* deservedly occupies the first place, as being in these Islands the main stuff of bread. It is universally admitted that the soils most suitable for this species of grain are those of a strong, loamy, and even clayey description; but it is not denied, at the same time, that where manure can be had in abundance, and the climate is not altogether unfavourable, Wheat may be raised successfully on lands of a much lighter nature. As far as our own experience goes, we should say that not less depends on the subsoil than on the qualities of the pulverized portion which is turned up by the plough; for as the fibres descend to a great depth in search of nutriment, the plants sustain a serious injury from contact with ferruginous ingredients, in the subjacent strata. Before the introduction of turnips and clover, all lands not decidedly cohesive were thought quite unfit for Wheat; but it is one of the many advantages arising from the use of green crops that new powers have been thereby added to the soil, and its capabilities enlarged.

Sowing.

Till a very recent period, Wheat was hardly ever sown but after a regular summer fallow; a method which is openly condemned by Mr. Young, in his *Calendar of Agriculture.* "If," says he, "there be one practice in husbandry proved by modern experience, to be worse than another, it is that of sowing Wheat in fallows. If fallows be thought necessary, let them be sown with barley, or oats, or any thing but Wheat. But Wheat may be advantageously cultivated after clover, tares, peas, beans, turnips, potatoes, and similar crops, regulating the succession according to the nature of the soil and the condition of the land." Beans which have been under suitable culture, are considered by him as the best preparation for Wheat; clover and tares being the next in order regarded as preparatory sowings. But whether Wheat be sown in fallow, or whatever may be the preceding crop, it is scarcely necessary to observe that the land should be in a friable and pulverized state, and completely cleared of weeds. When Wheat succeeds beans, the state of the weather will seldom permit more than one ploughing; for which reason, before this be attempted, the operation of cross-harrowing is strongly recommended, as well for the purpose of levelling the rows, as for clearing the surface from cumbersome weeds and straw. To preserve the crop from the effects of moisture, during the Winter, the ridges should be gathered up or raised in the middle, and the open furrows on each side be kept free from obstructions. When Wheat is sown after clover, a still greater degree of attention to the process of ploughing becomes necessary, in order that the grass roots may be completely covered; for when this part of the work is carelessly executed, the remaining stems vegetate and send up shoots, to the material injury of the young plants.

Varieties.

But the cares of the farmer are not confined to the cultivation of the fields meant for Wheat. He must exercise a similar vigilance and discernment in the selection of the seed; and this not only as it respects the quality of the grain, but the kind or species which may be proved most answerable to his soil and climate, which every day of the year either aid or oppose his exertions. The varieties of this grain are too numerous to be specified here; but the most general distinction is that which respects colour, the red and the white comprehending the intermediate shades. Wheats are again divided into Summer and Winter varieties; the former being usually bearded, while the latter sometimes shows a woolly ear and a very thick chaff. The white description affords flour of a finer quality than the red; but this disadvantage, in the case of the latter, is compensated by the property it possesses of coming more early to the sickle, and of growing on an inferior order of soils under a less genial sun. Summer Wheat has been long cultivated in some parts of England, particularly in Lincolnshire, and might probably be found to succeed in the more Southern Counties; but in Scotland it has not obtained any preference, even when used for a crop sown in Spring.

Pickling and steeping.

As Wheat-seed is sometimes prepared with pickles, or steeps and quick-lime, as a preventive of smut, we shall give a short account of a method which is followed in some districts with considerable success. Take four vessels, two smaller and two larger, the former with wire bottoms and of a size to contain about a bushel, the latter sufficiently capacious to contain the others within them. Fill one of the large tubs with water, and putting the Wheat in one of the smaller, immerse it in the water, stirring and skimming off the grains which float above, and renew the water as often as necessary till it comes off quite clean. Then raise the small vessel in which the Wheat is contained, and repeat the process with it in the other large tub which is to be filled with stale urine; and in the mean time wash more Wheat in the water tub. When abundance of water is at hand, this operation is by no means tedious; and the Wheat is much more effectually cleansed from all impurities, and freed more completely from all weak and unhealthy grains than can be accomplished by the winnowing machine. When thoroughly washed and skimmed, let it drain a little, then empty it on a clean floor, and riddle quick-lime upon it, turning it over and mixing it with a shovel, till it be sufficiently dry for sowing.

Agriculture.

M. Prevost's experiments.

The experiments of M. Prevost quoted by Sir John Sinclair, in a Work formerly mentioned, show in a striking light the advantage of previous preparation of the seed for the prevention of smut. The following were the results: 1. infected grain, without any preparation, had one-third of the crop smutted; 2. infected wheat, simply scalded, gave one-fifth smutted; 3. sound wheat, without any preservative, had one-fifth part infected; 4. infected wheat well moistened in a solution of blue vitriol, or sulphate of copper, in the proportion of nearly two ounces for three bushels of wheat, had only one-hundredth part affected with smut; 5. infected wheat, well moistened with a solution of the same kind, in the proportion of about four ounces and a half of blue vitriol to three bushels of wheat, gave only one three-hundredth part smutted. This solution is described as being equally efficacious in preventing mildew. The process may be more particularly detailed in these words: take three ounces and two drams of blue vitriol, and dissolve it in four gallons of cold water, the proportion allowed for every three bushels of the wheat to be prepared. Into another vessel capable of containing sixty or seventy gallons, throw from three to four bushels of wheat, and pour upon it the prepared liquid, till it rises five or six inches above the corn; stir it well, and remove the light grain from the surface. The wheat after being half an hour in the solution, is thrown into a basket to allow the liquid to drain off. The seed is then washed with pure water, and well dried before sowing. It is said that it may be kept after this process quite sound for several months. A similar application of blue vitriol is practised by Mr. Butler of Derbyshire. He dissolves two pounds of it in as much urine as will moisten twelve bushels of wheat, and after it has floated a sufficient time it is dried with quick-lime.

Blue vitriol.

Kiln-drying.

Another preventive of smut recommended to the practical Agriculturist is kiln-drying; an expedient, however, which must be adopted with great care, as the slightest excess of heat might destroy the powers of vegetation. A practice has likewise been introduced by some farmers of passing their seed wheat through rollers, by which means a black powdery matter is separated from the surface of the grain. This also is a method which, however successful it may have proved in judicious hands, must not be hastily imitated, there being a manifest hazard that part of the corn shall be lacerated, or otherwise injured.

Rolling.

Quantity of seed.

No fixed rule can be laid down as to the quantity of seed which ought to be given to an acre of land suitably prepared for wheat; because this is a point of practice which must be determined in every case by a reference to the fertility of the soil, the nature of the climate, and even the period of sowing. On a rich field brought by culture to a good condition and sown early, the quantity need not exceed two bushels. In no instance should it pass three bushels per acre; although on bean-stubble the allowance should certainly be more liberal than on fallow or after a green crop.

Modes of sowing.

In regard to the particular modes of sowing, we have already said all that appears necessary. Our reasons for preferring the drill-system to the more ancient method of broad-cast are founded on experiment and long observation; and wherever the land will admit of it, the farmer will find the expense of labour and machinery amply repaid. The method of *ribbing*, as it is called, or the making of small furrows at the distance of nine or ten inches, answers nearly the same end as drilling. The seed, it is true, is scattered by the hand in the usual broad-cast manner, but as it necessarily fall, for the most part in the furrows, the crop rises in parallel rows, and the ground is levelled by harrowing. This plan has nearly all the advantages of the other, so far as respects the rays of the sun and the circulation of air among the plants; but as some shoots will unavoidably spring up between the lines, it is not so well fitted for the operations of clearing, weeding, and hoeing. In the County of Norfolk, the Dibbling of wheat is still practised to a considerable extent; though we do not find that it is attended with any advantage except the sowing of seed. An expert dibbler, with the assistance of three children to drop the grains, sows about two roods a day; the quantity expended being from four to six pecks per acre, proving a gain on that article to the amount of nearly a bushel on four roods. Some attempts have been made to introduce machinery for this purpose, but hitherto without success.

Ribbing.

Dibbling.

After the usual operations of culture and sowing, the anxiety of the farmer is confined to the two essential points of keeping the field free from weeds and superabundant moisture. No water should ever be allowed to stagnate on the surface of the ridges, or even in the open furrows, otherwise the seed rots and perishes, or if it escape total destruction, it sends forth sickly plants which never come to perfection. Where the broad-cast method of sowing is continued, the process of clearing cannot be fully accomplished; being confined to such weeds as can be removed by the hand. But wherever wheat is drilled, the business of hoeing can be effectually executed; a species of labour which is not less beneficial to the crop by stirring the soil and closing it in the roots, than by eradicating the intrusive vegetation by which it would soon be encumbered. It has been ascertained that by loosening the earth and gathering it round the stems of plants, *tillering*, or the production of new stalks is greatly promoted, and particularly in the drill-husbandry. Some curious facts are recorded of the wonderful multiplication of stems effected by this process. In a moderately good crop of drilled wheat, Sir H. Davy counted from 40 to 120 stalks springing from a single grain; and he quotes Sir Kenelm Digby who saw in the possession of the Fathers of the Christian Doctrine at Paris a plant of barley which they preserved, and which consisted of 249 stalks from one seed, and yielded 18,000 grains. He refers also to Mr. Miller of Cambridge, who sowed some wheat on the 2d of June, and on the 8th of August a plant was taken up, separated into eighteen parts, and replanted. In September and October, they were again taken up, and divided into sixty-seven separate parts, to remain during the Winter; and in March and April they were also taken up, when they produced 500 plants. The number of ears from a single grain amounted to 25,509, and the grains were estimated at the amazing number of 576,840. The produce weighed nearly forty-eight pounds, and measured three pecks and three-quarters of a peck.

Hoeing.

Multiplication of stems.

In some districts we have observed the practice of turning in cattle into a field of wheat, *to feed it down*, when it appeared too luxuriant at an early part of the season. Some benefit was supposed to be derived from the removal of the upright stems by which the growth of the lateral shoots become more vigorous; but if this practice be ever useful, it must be confined to cases of excessive luxuriance, and where the land is of a firm texture. In short, it can only be regarded as a hazard-

Feeding down.

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ous alternative, resorted to when the crop would otherwise be certainly lost.

Diseases smut.

The principal diseases to which wheat is exposed are the *smut* and *mildew*. The former appears in the shape of a black ball, which occupies part of the ear, and thereby not only so far diminishes the produce, but contaminates, more or less, all the sound grain, rendering it unwholesome food, and quite unsuitable for seed. A remedy has been already suggested for this evil, as it is understood by all intelligent Agriculturists to be perpetuated by means of propagation, or, in other words, that diseased corn is always reproduced in an unhealthy state. But a more certain preventive will be secured by the resolution never to sow wheat which has been even in the slightest degree tainted with smut.

Mildew.

The ravages of *mildew*, in particular cases, are even more destructive than that of the pernicious blight just mentioned. It is generally imagined to originate in a disordered state of the atmosphere; and when it takes place between the periods of flowering and ripening it has been known to lay waste whole fields in the course of a week. Nor have any means been discovered for putting a stop to so fearful a malady. As it prevails more or less in some situations every season, whatever may be the state of the weather, a cause has been sought in the vicinity of certain plants, the fungous substances attached to which bear a great resemblance to the straw of mildewed wheat. The barberry and several other shrubs have been suspected of extending this evil among the cereal tribes; and various ingenious speculations have been formed to account for the mode of infection. The communications of Sir Joseph Banks to the Board of Agriculture give the fullest view that is anywhere to be found of this obscure inquiry; though it must be acknowledged that his researches were not attended with any practical advantage to the farmer, or with any new lights useful to the Botanist.

Amount of produce.

The amount of the produce raised on an acre of good wheat land varies, in every County, and in every season, from three quarters to ten. We have known a whole field average ten quarters of good marketable grain, a return which may be expressed in another form as equal to eighty Winchester bushels per acre. But perhaps, even in the present improved state of Agriculture, we ought to consider one-third of that quantity as the usual return throughout the Kingdom.

Barley.

Succession.

We proceed now to *Barley*, in regard to which every one knows that it grows best on light loams, and even on a sandy soil, if properly manured. It usually succeeds turnips, potatoes, beans, peas, or tares. But whatever may be the crop which precedes it, the soil must be brought by repeated ploughings to a pulverized state, so as to ensure an equal vegetation. In Suffolk, when Barley follows turnips, it has long been a practice to drill the seed without ploughing; whereas in Norfolk, where this crop is carried to great perfection, the land is carefully prepared by the most assiduous labour. Of this grain there are several species cultivated in Britain, and even different varieties of these species. The two-rowed species, or *Hordeum distichon* of Linnæus, includes sundry varieties, which are known by familiar names among the rustics of both divisions of the island. The early and late, or *hot* seed and *cold* seed, are distinctions universally recognised. To the first of these belongs the Scotch barley, as well as the Rathripe, Hotspur, and Sprat, which are also denominated the Battledore, Fulham, and Putney, from being cultivated in the neighbourhood of those places. The second species is the *Hordeum vulgare*, or *tetrastichon*, which is likewise described as *bear* or *bigg* in the Northern Counties, and is found to answer well on elevated situations and inferior soils. The *Hordeum hexastichon*, or six-rowed Barley, is a species which has a strong reed or straw, grows rapidly, and ripens early, is very hardy, and withstands the severity of Winter; whence it derives its characteristic appellation of *Winter Barley*. It is very generally cultivated in Russia, and as far North indeed as any corn is raised; but as the quality is rather coarse, and fitter for meal than malting, it has not obtained a very favourable reception among our farmers, especially in the more fertile parts of the country.

Varieties.

Sowing.

From the beginning of April to the middle of May is esteemed the best time for sowing Barley; bear or bigg, being an earlier, as well as a hardier kind, may be sown somewhat later. As it suffers much from weeds in a wet season, it ought to be drilled rather than sown broad-cast. The quantity of seed varies according to the condition of the land from two to four bushels. We may remark that of late years it has become customary to throw Barley into the ground at an earlier period than formerly; and hence nothing is more common than to see our farmers occupied with this crop about the middle of March. In some cases, Barley comes up irregularly and ripens unequally. To obviate this inconvenience it has been recommended to steep the seed before committing it to the soil, not only to promote a more rapid vegetation, but to render it more uniform. Some Agriculturists add a little soot to the water, with the view of destroying vermin, which are occasionally found to attach themselves to the husk of the grain.

Care in Harvesting.

No crop requires greater attention in harvest, especially in bad weather, than Barley. When it is fully ripe the straw becomes brittle, so that the ears are exceedingly apt to break off, if frequently or roughly handled. The intelligent farmer, therefore, cuts it down, while the straw yet retains a certain portion of its sap and the grain is not fully hardened. Similar care is necessary in threshing, especially in separating the spikes, or *awns*, as they are provincially denominated, from the ear. For this purpose, some threshing mills are furnished with what is called a *hummelling* machine; and where this is wanting, it is customary to put the grain, accompanied with a portion of threshed straw, a second time through the threshing apparatus. Where Barley has been mown, the whole of the straw requires to be twice threshed, independently of the necessity of getting rid of the spikes, which sometimes adhere tenaciously to the grain, if not completely ripened.

Produce.

The produce of Barley, taking the average of England and the South of Scotland, has been estimated at thirty-two bushels; but when Wales and the North of Scotland are included, where, owing to the imperfect modes of culture still practised, the crops are very indifferent, the general average over the whole will not perhaps exceed twenty-eight bushels per acre. Restricted to the County of Middlesex, the average produce is rated at four quarters of grain and two loads of straw.

Rye.

Rye, although less used in Britain than other culmiferous crops, is nevertheless entitled to a place in the list of our Agricultural productions. It is said to be a native of Crete; but it is doubtful whether it can now be traced to any particular Country. It has been cultivated in Europe from time immemorial, and is considered as coming nearer in its properties to wheat than any

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other grain. In most parts of the Continent it is more common than wheat, being a more certain crop, and one which requires less culture and manure. It is the bread corn of Germany and of Russia.

Varieties.

The varieties of it are confined to two, the *Winter* and the *Summer*; but there is so little difference between them, that if sown at the same time and in the same field, they can hardly be distinguished from each other. Though it has been considered as the most impoverishing of all crops, it is admitted that it will make a good appearance on a soil much inferior to that required for wheat. It will also prosper in a colder climate, though it is liable to be injured by rains during the Winter as well as in the flowering season; and in these respects it bears some resemblance to the finer grain with which we are now comparing it.

Sowing.

Rye is sown either in Autumn or Spring, and either in broad-cast or in drills; two bushels and a half being the usual allowance to the acre when deposited in the former manner. No pickling or other preparation is given to the seed, there being no reason to apprehend the diseases which that treatment is meant to obviate.

The spur.

The *spur*, or *ergot*, is by some considered as a fungus, a species of *sclerotium*, somewhat analogous to that which occasions the smut. It is not peculiar to Rye, though it is seldom seen on any other gramineous plant. It is the production of the seeds; is long, horny, and cartilaginous; is sometimes straight, at others curved; and is occasionally found more than two inches in length. The resemblance of this substance to the spurs of a cock has procured for it the name by which it is distinguished. On breaking a spurred seed you find within it a matter of a dull white colour, adhering to the violet skin which surrounds it. Rye thus attacked cannot germinate; and it may be remarked in regard to other grain, the most rainy years are the most productive of this disease; that high grounds were nearly free from it; and that even the lower parts of the same field were more affected than the upper parts. In France, a malady called the chronic, or dry gangrene has been produced by eating ergot or spurred rye. The same effect has been marked in Switzerland, where, it is added, most animals refused to eat the distempered corn. The Royal Society of Medicine at Paris employed M. Tessier, a distinguished Agriculturist and man of Science, to go into the Countries in which the dry gangrene prevailed, and collect a sufficient quantity of cock-spur Rye for the purpose of making experiments. The result confirmed the opinion of those who attributed the human disease to that of the vegetable. Such Rye sometimes appears in this Country, but no instances are recorded of its producing any such effects; but Dr. Wollaston has stated in the *Philosophical Transactions* several cases in which dry gangrene was occasioned in one family by eating damaged wheat; and nearly the same consequences were produced in a household in Wiltshire by the *Colium temulentum* entering largely into the composition of bread. M. Lagusca relates that the ergot is covered with a thin pellicle, and filled with a grey powder. It is collected as a medicine in Spain by women and children, who wade in the fields of standing Rye for the purpose; but as only a very small quantity can be obtained, it is sold at a high price as an article of the *Materia Medica*.

Culture, &c.

The culture, harvesting, and threshing of rye does not differ essentially from the same processes as applied to wheat; and the produce, in similar circumstances, is nearly equal. Sir H. Davy found in one thousand parts of Rye, sixty-one parts of starch and five parts of gluten. Professor Thaer maintains that Rye is the most nourishing grain next to wheat. It contains an aromatic substance, which appears to adhere more particularly to the husk, since the agreeable taste and smell peculiar to Rye-bread, are not found in that which is made from Rye-flour which has passed through a very fine bolting cloth; while the fragrance may be restored by a decoction of Rye-bran in the warm water used to make the dough. This substance is thought to facilitate digestion, and to have an action peculiarly fortifying and refreshing on the animal frame. In this Country accordingly, Rye is chiefly used for gingerbread, and abroad in the distilleries, where it affords a powerful and exhilarating spirit. The best Hollands is made of Rye, well selected and prepared by the manufacturer. The straw, too, is much prized for work, resembling that of Dunstable.

Oats.

Next to wheat and barley there is no grain more common in the Northern parts of Europe than *Oats*. Although its native Country be unknown, the culture of this valuable crop is confined in modern times to districts of which the latitude is higher than the middle Provinces of France. In the Southern Departments, as well as in Italy, Spain, and Portugal, it is almost entirely unknown; being unsuitable to the climate not less than to the wants of the people. Oats require an atmosphere which is at once cool and moist; for in the absence of rain, and affected by a temperature above sixty degrees, the panicles become so contracted that they cease to afford sufficient nourishment to the ears, which thus never become plump, but are thick in the husk, long-awned, and unproductive in meal. This is very often the case with oats in Scotland in a dry year, and in the South of England almost every season.

Varieties.

There are many varieties of this corn, which are known to the farmer under a corresponding number of descriptive appellations. First there is the white or common Oat, then the black, the red, the Polish, the Dutch, the Potato, the Georgian, the Siberian, the Angus, the Blainsley, the dun, and the Winter Oat. The Potato, which is distinguished by having large, white, plump grains, is now almost the only Oat raised on well-cultivated lands, whether in England or Scotland, and usually brings a higher price in the London market than any other variety. It may be remarked, however, that, while the Potato and Polish are the fittest for low situations, where the soil is rich and the air warm, the red kind answers best on elevated grounds and under a less genial climate.

Culture.

Oats grow well on any texture of land, from the stiffest clay to moss or bog, provided it be sufficiently dry. Nor does the soil on which they are cultivated require any great degree of preparation. It is generally the first crop sown on newly broken-up grounds, as the radical fibres do not, as in the case of wheat and barley, depend on that pulverized condition of the mould which results from protracted labour. In regular rotations this usually follows grass; sometimes, upon land not rich enough for wheat, that had been previously fallowed or had carried turnips, after barley, but rarely after wheat, unless from particular circumstances cross cropping becomes a necessary evil. One ploughing is generally given to the grass lands, commonly in the month of January, so that the benefit of frost may be gained, and the surface rendered sufficiently friable for receiving the harrow. In some cases a Spring furrow is given when

Oats succeed barley or wheat, especially when grass-seeds are to accompany the crop. The best Oats both in quantity and quality, are always those which succeed grass; indeed no kind of grain seems better fitted by Nature for foraging upon grass lands, as a full crop is usually obtained in the first instance, and the field left in good order for succeeding ones.

Sowing. The season for sowing this corn extends from the beginning of March to the end of April. About the middle of the former month is the time fixed on by the best farmers. In some parts of Ireland, the Dutch Oat is sown in Autumn; in consequence of which it is ripe nearly a month earlier than such as is postponed till Spring, an object worthy of attention in so moist a climate.

Produce. As Oats are more carefully cultivated in the Northern Counties than in those Southward of Trent, the produce in the former is correspondingly greater, amounting in some cases to fourteen or fifteen quarters per acre. It is a grain besides which is subject to much fewer diseases than the more delicate species of corn. The smut sometimes, indeed, makes an inroad upon it, but the injury which is oftenest inflicted upon it arises from wire-worms, that is, the *larvæ* of insects which generally abound in lands newly broken up from turf. **Wire-worms.** The best mode of obviating this serious evil is to put off the ploughing of the field till the period at which it is to be sown; for by this means the insect or grub, as it is usually called, is turned down, and before it can work its way to the surface, the corn has grown up beyond its reach. In this way gardeners destroy or retard the progress of the gooseberry caterpillar by digging under the bushes; for it is found that the eggs and *larvæ* of insects, like weeds and bulbs, when buried too deep in the ground, have their period of vegetation delayed, and sometimes the vital principle entirely extinguished.

Value of straw. Every one knows that the straw of Oats is more valuable as forage than that of any other corn crop, and is even advantageously used as a substitute for hay during the Winter months, both for farm horses and cattle, in some of the best cultivated districts in the Kingdom.

Peas and Beans. *Peas* and *Beans* were at one time more generally cultivated than they are at present, being regarded chiefly as the means of cleaning foul ground, and preparing it for wheat or barley. But since the use of green crops has in a great measure superseded the necessity of that expedient, Beans are confined almost exclusively to clays and strong loams, on which turnip cannot be successfully raised. There they succeed wheat or oats, and sometimes also clover or pasture grass.

Culture. In preparing ground for Peas and Beans, it ought to be deeply ploughed in Autumn or early in Winter; and as a second or even a third furrow must be given in the Spring, it is usual to make one of them a cross-ploughing. The mode of manuring depends upon that of sowing. If the seed is to be scattered in the broad-cast way, the dung should be ploughed down in the fall of the year; but if it is to be deposited in the furrows or in drills, the manure should be laid in with it, so as to afford the most speedy and active cooperation with the soil. The remarks which have been made on drill-husbandry in general apply to the management of this crop, and need not be repeated. Suffice it to add, that Beans when sown alone are commonly planted in rows, at the distance of nine, eighteen, or twenty-seven inches; the last being the usual interval when they are meant to be cultivated by the labour of horses instead of hand-weeding and hoeing.

Sowing, &c. The time of sowing varies from the end of January to the end of March. Both in the broad-cast and drill husbandry, it is common to mix a few Peas with the Beans, because the mixture at once improves the quality of straw when used as fodder, and affords a ready means of binding the sheaves in harvest. The most approved method of reaping this crop is with the sickle, but it is sometimes mown, and in a few instances pulled up by the roots. **Produce.** The amount of produce, as in the case of all pulse grains, is very variable and even precarious; and were it not that it is still esteemed an improving crop, it would not be so generally adopted without the certainty of a higher remuneration in the market.

Tares. *Tares*, which in some parts of the Kingdom occupy a considerable share of attention, are found to succeed best on gravelly loams; but they produce a tolerable crop on almost every variety of soil, if properly cultivated and manured. **Varieties.** There are two varieties of the Tare, distinguished chiefly by the period of sowing, the *Winter* and the *Spring*; and although it be difficult to discriminate the seeds of these varieties, they should always be kept separate, because each thrives decidedly best in its own season. Winter tares are sown from August till October; earlier on poor soils and exposed situations than on richer and more sheltered lands. The plants should be fully established in the soil before the approach of the cold weather. The Spring kind is sown about the beginning of March, when it is intended to ripen the seeds; but when the crop is to be used as green food, the process may be postponed two months later. Sometimes the insertion of the seed of Spring Tares is delayed till June, when a quart of coleseed is given to each acre, for the purpose of supplying weaned lambs in Autumn with an excellent food. This method is successfully practised on the Down lands in the County of Sussex.

Sowing. Tares are generally sown broad-cast, although, on good soils, drilling is found to remunerate the additional labour by a more abundant return. **Produce.** In Middlesex the produce amounts to about twelve tons per acre, which, when converted into hay, is reduced to three or four tons according to the nature of the season. The most beneficial application of this crop is soiling with horses or other live stock on the farm; but for this purpose it should be allowed to reach a considerable degree of maturity. All descriptions of animals thrive upon it. A single acre of Tares has been known to maintain four horses in better condition than five acres of grass; and twelve horses and eight cows have been kept three months upon eight acres of Tares, without the addition of any other food. It is asserted, too, that the milk of cows fed with this vegetable is so much improved that it yields a greater proportion of butter than can be produced by the best grass-feeding.

Useful species. Some other species of this plant are recommended to the attention of the Agriculturist; such as the *bush vetch*, which shoots early in the Spring, vegetates late in Autumn, continues green all Winter, is excellent pasture, and on fertile soils might be converted into hay; and secondly, the *tufted vetch*, which rises to a considerable height, and affords abundant foliage, so that it might likewise be used as green fodder, or prepared for hay. Lean cattle, it is said, have been greatly improved by feeding on it. The *everlasting pea*, or *Lathyrus latifolius*, is likewise a plant of large growth and foliage,

Agriculture. and has been warmly recommended as a good material for green food or hay, being of a very nutritious and fattening quality. *Buck-wheat* is occasionally cultivated for the same purpose, as well as *chicory*, or *wild succory*, also a succulent, herbaceous plant extremely useful in the dairy and feeding-house.

Potato. There is no production of the soil which the necessities of life have of late years raised into higher importance than the *Potato;* native of a warm climate, and yet naturalized in all the Countries of Europe. Its history is involved in some obscurity, and the precise period of its introduction has not yet been ascertained. From the History of Plants by Gerard, published in the year 1597, there is no doubt that the Potato was known in England at a somewhat earlier period. He speaks of two kinds, the *common* and the *Virginia*, which he cultivated in his garden; and yet nearly a century and a half elapsed before this valuable root became a general article of food.

Varieties. The varieties of this plant are now almost as numerous as that of the dog; the distinction being founded chiefly on the colour of the Potato itself, or of the flower which it exhibits when in full growth. In Lancashire, where it is cultivated with much attention, there are known no fewer than twenty varieties of the early description, and fifteen of the late. But this minute subdivision might be carried to a still greater extent. New varieties are obtained every day by raising a crop from seed, by which the quality and productive powers of the plant are said to be greatly improved. When the apples come to maturity and begin to drop from the stem, they are collected and preserved among sand till the Spring, when they are bruised either among the sand, or fresh mould procured for the purpose, by means of which the seeds are separated and mixed with the earth. They are then sown or scattered on a well-prepared or garden soil; and when the rough leaf appears, and the plants have sufficient strength to be safely handled, they are removed to another bed of fresh mould, where they are placed in rows and kept free from weeds during the Summer. In Autumn clusters of small Potatoes are found at the roots; these are planted next Spring, and so on successively three years, at the end of which they attain their full size. It must be noticed, however, that the earlier varieties do not bear flowers, and consequently, do not produce apples; but by removing the earth from the roots, and the small Potatoes themselves as they began to form, Mr. Knight, the President of the Horticultural Society, succeeded in forcing the plant into blossom, and thus obtained seeds from the early as well as the common kinds.

Culture. The Potato loves a soil which is rather loose and porous; nothing being more fatal to its success than stiff, retentive land. In many parts of Ireland, it is planted on what are called lazy-beds; the sets being placed on the surface, and covered with earth dug out of a trench formed round them. But good farmers prepare their fields for Potatoes nearly in the same manner as is practised in turnip husbandry. The land is usually ploughed in Autumn, an operation which is repeated once or twice in the Spring; and a copious supply of manure is deposited with the seed, either in furrow or drill. Some Agriculturists have discovered an advantage in bestowing a plentiful dunging on the previous crop, rather than on the Potatoes themselves; for in this way the excessive luxuriance of the stems is prevented, while the quality of the root is greatly improved.

No crop is more benefited by the care which is bestowed on weeding and hoeing. The earth ought not only to be kept clean, but also to be frequently stirred, and raised round the roots of the plants at the several stages of their progress. As the Potato is now almost universally cultivated in drills, the greater part of the labour is performed by horses; but whatever may be the species of industry required, the farmer should not withhold it, for nearly in proportion to his exertions in that way, will be the amount of his produce. Agriculture. Stiring the earth.

It has been found by those who have instituted experiments on the comparative advantage of planting entire Potatoes of a larger or smaller size, cuttings of different sizes with one or more eyes, or shoots only, that middle-sized whole Potatoes, or large cuttings of large Potatoes, afford better crops than smaller Potatoes entire, or small cuttings, or the eyes or shoots alone. Considerable diversity, too, in the amount of the produce was occasioned by placing the sets in the rows at various distances, from six to twelve inches. With the view of saving seed in times of scarcity, the shoots only are employed; but this economy is counterbalanced by many disadvantages. The shoots cannot be planted so early; many of them being weak afford little or no produce, and the crop is generally later in reaching maturity. In the use of the eye, or root-bud of the Potato, the success has been various. In some cases the produce seems to be equal to what was obtained from larger sets; but in others, feeble stems and a diminished return have afforded ample evidence that this mode of propagation ought not to be relied upon by the British farmer. Planting.

The prevailing disease of the Potato is the *curl*, which originating in Lancashire in the year 1778, soon spread very rapidly, especially in those districts where the culture of this valuable root was the most extensive. The alarm excited by this occurrence led to numerous investigations with the view of discovering the cause. At present the opinion on this head, which seems deserving of the greatest attention, is that entertained by some members of the Caledonian Horticultural Society, who ascribe the malady to an undue ripeness of the seed. To procure, therefore, a sound, healthy stock, it is recommended to select seed from a high part of the country, where owing to climate, and other circumstances, the tubers are never over-ripened. With the same view, such Potatoes as are intended to supply seed for the following season, should be planted at least a fortnight later than those which are meant for the table, and taken up as soon as the stems begin to display a yellow-green colour. Diseases. The Curl.

Among the various methods which have been devised for increasing the produce, it has been a practice with some Agriculturists to cut away those parts of the plant which contain the flower before the blossom appears. It has been ascertained by Mr. Knight that this vegetable possesses two modes of securing its reproduction; the one by producing tuberous roots, and the other by the general mode of flowers and seed-vessels; and that in both these operations. Hence it has been inferred that if we can prevent the consumption of it in either of them, we shall make it act more strongly in the other. On this principle, if a Potato plant is carefully deprived of its tubers as soon as they are formed, it will be made infinitely more productive of blossoms and seeds. On the other hand, if its blossoms are picked off, and it is prevented from forming any seed at all, the fluid which would have been employed in that opera- Cutting the blossoms.

Agriculture. tion, will be expended in forming an increased crop of tubers.

Produce. In regard to the average produce, we cannot form an accurate judgment without taking into account such a variety of circumstances of culture, fertility, and climate, as would render the result inapplicable to any great extent of country, even in the same neighbourhood. It has been stated by some writers to vary from five to ten tons, according to the nature of the soil, and the skill of the husbandman. In Yorkshire, from 300 to 400 bushels of the finer variety, and from 400 to 500 of the coarser sort, are considered a good crop. We have heard that, in some districts of Kent, more than 600 bushels have been raised from an acre, and that even a much larger amount has been obtained, in a very favourable season, and from a soil peculiarly rich.

Turnip. Next to potato in importance we may place Turnip, viewed at least as the means of improving land, of supplying to the Agriculturist a valuable species of food for his cattle. The introduction of this plant, together with clover and the artificial grasses, formed a new era in the progress of our native husbandry. It is true that Turnip does not succeed on every kind of soil, particularly such as are stiff and clayey; but on dry loams, and indeed on all of a loose texture, managed according to the best courses of cropping, it enters into rotation every fourth or sixth year. The species usually cultivated in the improved districts are the *white globe*, which ripens early, and gives a full crop; the *yellow*, which has the advantage of being more hardy, and is usually meant to follow the other in Spring; and thirdly, the Swedish or *ruta baga*, which may be preserved for consumption till the end of May.

Varieties.

Culture. To secure a good return the farmer must have his land well pulverized, and cleaned. The manure ought also to be carefully prepared, and in a state of minute division, otherwise the work will be clumsily performed, and much of the seed lost. We need not add that the process of sowing is usually conducted by means of the drill-machine. The time of sowing the several varieties is somewhat different; the Swedish being put in first, and the yellow, and both about the end of May. But as these kinds are much less extensively cultivated than the white, the principal seed-time takes place in the month of June. The quantity of seed allowed to the acre does not exceed two pounds, which, though more than sufficient to stock the ground with plants, is thought necessary for securing a good crop on most soils. As soon as the rough leaf, as it is called, is developed in the young shoot, the hoes must be employed to thin the rows, and destroy the most obtrusive weeds. Next follows the horse-hoe to stir the soil and clean the surface; an operation which it is sometimes necessary to repeat, should the field not have been brought into good order by previous ploughing and eradication.

Injurious insects. So far as labour is concerned there is no ground, generally speaking, to dread the failure of a crop in an ordinary season. But the husbandman has obstacles to encounter which no care can remove, and, we may add, which no care can altogether obviate. His greatest enemy is the Turnip fly, the *Chrysomela saltatoria* of Linnæus, which by preying upon the leaves of the young plants very soon destroys them. The canker, so much dreaded in Norfolk, is to be referred to the ravages of another insect, the *Tenthredo oleracea* of the same Naturalist, which is wafted over in myriads with the North-East wind from the Continent, and in the course of a day or two covers whole fields. The black caterpillar commences its depredations on the Turnip plants after they have made some progress; and it is sometimes assisted in its work of destruction by the grey slug, not less formidable in certain situations than any of the others.

Remedies. Various means have been devised to prevent the ruin occasioned by these insects, but hitherto without success. It has been recommended to steep the seed in water, train-oil, linseed oil, or some similar fluid, twenty-four hours, and after mixing it with finely sifted earth, to deposit it immediately in the drill. The strewing of quick-lime, vegetable ashes, soot, or barley chaff, and the sprinkling of lime-water, tobacco-water, and some other liquids, have been practised for the destruction of the fly and slug. Rolling the ground with a heavy roller in the night, when the insect proceeds from its lurking place, has been adopted by some farmers, but with doubtful success. It has been suggested that as the radish leaf is preferred by the slug to that of the turnip, a little of the former should be sown along with the latter; and as the radish appears first, the chance of an escape is thereby secured for the main crop.

Other diseases. But Turnips are, besides, exposed to a disease in the root. A large excrescence forms below the bulb, which after a certain period becomes putrid, and emits a very offensive smell; an affection which has been ascribed to a puncture made by a grub or other insect in the vessels of the tap-root. It occurs most frequently in dry seasons; and the only antidote that has been devised is to enrich the land by means of assiduous culture and good manure. There is another distemper familiarly known in the country by the name of *fingers and toes*, when the plant, instead of forming bulbs, sends off a number of separate roots. In some cases the bulb itself is divided into lobes, but very often the tap-root is the part affected while the bulb remains untouched. These unhealthy indications are frequently observed at an early period, and sometimes before the appearance of the rough leaf. All inquiries into the history or origin of this disease have failed to discover its true source; at least it cannot be traced to any peculiarity in the seed, the period of sowing, or even in the soil. Some writers have conjectured that it may be occasioned by a wound inflicted on the roots by an insect too small to be observed, or which retires after it has done the mischief. Marl, or fresh mould mixed with lime, has been applied to the land as the only remedy which seemed likely to prove effectual.

Produce. The produce of a Turnip crop varies to a great degree in different Counties, according to the nature of the soil, the management, and the weather. Fifteen tons are reckoned a moderate return, and perhaps the weight does not average much higher throughout the Kingdom; but we have known instances where it amounted to fifty, and have heard of others still more abundant.

Carrot. The *Carrot*, though long grown in our gardens, is comparatively but of recent introduction into Agriculture. It seems to have been cultivated from an early period in Germany and Flanders, and brought over from the latter Country to Kent and Suffolk, in the XVIth Century. As it requires a deep soil inclining to sand, it can never be so generally raised as the potato and turnip, which come to maturity on a greater variety of grounds. On other accounts it is less prized, as a regular crop, by Agriculturists than it was a few years ago; and even in Norfolk, where it was very successfully cultivated, we

Agriculture. are informed that it is sown in much smaller quantities than it was about the beginning of the Century. It is said that the consumption of Carrot seed in that County alone has diminished from three or four tons a year to as many hundred weights.

Varieties. The varieties of the Carrot which appear in our gardens are numerous, and may be increased to a great extent by the usual means; but the only sort adapted for the field is that which is called the long red. The farmer should be aware that new seed is most essential, as it will not vegetate the second year.

Culture. We have already stated that the best soil for the Carrot is a deep rich sandy loam; and in preparing it for crop it ought to be ploughed before Winter, in order that it may be pulverized by the frost, and in the Spring well stirred to the depth at least of a foot. This deep tillage may be perfectly accomplished either by means of the trench-plough following the common one, or by the common one alone with a good strength of team; but the former method is to be preferred wherever the lands are inclined to be stiff or heavy. In Suffolk, the farmers sow Carrots after turnips, barley, and peas, set upon a rye grass lay; the crops upon the first have generally been most productive; next to that they prefer the last. In the former case, they feed off the turnips by the beginning of February, and then lay the land up in small balks or furrows, in which state it remains till the second week in March, when it is harrowed down, double-furrowed to the depth of about twelve inches, and the seed sown.

In regard to climate, the Carrot and turnip require nearly the same temperature; but the former, from the depth to which the roots penetrate the soil, thrive better than the other in dry warm weather. The season for sowing is the last week in March, or the succeeding one in April; though the first is generally preferred, it being found that the early crop is usually the most productive.

Manuring. According to some authors, manure should not be given to Carrots the year they are sown, as it is alleged that when the roots come in contact with it they become forked, scabbed, and wormy. This, however, will only take place in cases where recent unfermented dung has been applied; or where other manure has not been properly divided and broken into small pieces. The best farmers in England always use manure; for, though it has been found that good crops may be occasionally raised in a rich soil without it, the general rule is, that a liberal allowance of the best dung is quite essential to an abundant return in ordinary circumstances.

The usual preparation of the seed for sowing is to mix it with earth or sand to make it separate more freely; but some add water, turning over the mixture several times, and thus bringing the seed to the point of vegetation before it is sown. In France, night-soil is sometimes used instead of earth, and the drainings of a dunghill instead of water. The quantity of seed when Carrots are sown in drills is estimated at two pounds, while for broad-cast three times as much is found necessary.

Produce. The produce of an acre, according to Mr. Young, averages three hundred and fifty bushels; but Mr. Burrows states, in his communications to the Board of Agriculture, that his land yielded eight hundred bushels per acre, a produce which considerably exceeds the largest crop of potatoes.

Uses. The Carrot is extremely valuable as an article of rural economy. It is used for feeding all kinds of stock, serves well in the dairy, and is equal to oats for the sustenance of labouring cattle. The quantity of nutritive matter in this plant, as ascertained by Sir Humphry Davy, amounts to ninety-eight parts in one thousand, of which three are starch, and ninety-five sugar. Owing to this circumstance, they yield more spirit to the distiller than the potato, averaging, it is said, twelve gallons per ton.

Mangold-wurzel. The *Mangold-wurzel*, or *field-beet*, has of late years been pretty generally cultivated in some of the most improved districts of the Kingdom. It is supposed to be a mongrel between the red and white beet, though it has a much larger bulb than either, which in some varieties grows in great part above the ground. It has been a good deal cultivated in Germany and Swisserland both for its leaves and roots; the former are used either for spinach or given to cattle; and the roots are set apart, as well for the latter purpose as for the distillery and sugar-house. It has been doubted whether it possesses any advantages over turnip for the general purposes of Agriculture; and perhaps the main ground of preference consists in its adaptation to more tenacious soils than answer for turnip, and in its being less exposed to depredation in the neighbourhood of large towns. It has been ascertained that any kind of land will suit this plant, provided it be rich; and immense crops of it have been raised even on strong clays. The variety which is most esteemed in Germany is slightly tinged with red, although for distillation and the manufacture of sugar, a selection is made of that particular kind which is distinguished by a pale yellow colour.

Culture. The ground should be prepared for it exactly in the same manner as for turnip, and the process of sowing should be conducted on the system of drill husbandry. Some farmers, however, prefer to dibble in the seed, as they are thereby saved the expense of thinning. In either case, the work should be done about the middle of April. The produce of this crop, in similar circumstances, does not fall short of Swedish turnip; but the nutritive matter afforded by mangold-wurzel is considerably greater. In 1000 parts, that matter amounts to 136, of which 13 are mucilage, 119 sugar, and 4 gluten. Hence it is manifest that an acre of it will afford more nourishment than turnip, carrot, or parsnips. As food for cows, it has generally been preferred, as it gives no bad taste to the milk or butter. Near London, it is very much used for this purpose; the tops are first taken off and given by themselves; and then the roots are taken up, washed, and given raw. In Britain, the abundance of corn and sugar has precluded the use of this vegetable from entering into our manufactures; but in France the processes introduced during the dominion of Bonaparte have not yet been everywhere relinquished.

Parsnip. The *Parsnip* has not yet been so generally received into British Agriculture as to merit much attention in an outline of our crops. In Jersey, where it is extensively cultivated, beans are commonly grown along with it; the former being first dibbled in, and the latter afterwards sown broad-cast. For fattening cattle, it is considered equal, if not superior to carrot, as it gives an exquisite flavour and juicy quality to the meat. It has the same good effect on milk and butter when cows are fed on it. When sown in drills, the quantity required is about two pounds the acre, and the proper season is the month of February. But notwithstanding the inducements now mentioned to the culture of this crop, it will not, it is probable, ever take its place in a regular rota-

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tion; because while, like carrot, it requires much manual labour, the variable nature of our climate must ever render the return very uncertain.

Cabbage.

The *Cabbage*, though a nutritious plant, and quite suitable for field cultivation, has not been found profitable as an article of Agricultural industry. One reason why so much has been said in its favour, by Mr. Young and other writers, whose experience has been confined to the Southern Counties of England, may be discovered in the circumstance that they compare its produce with the quantity of turnip raised on an equal space of land. But it is well known that from the nature of the soil, the climate, and the mode of husbandry, the weight of turnip raised in those districts falls greatly short of the average amount as applied to the Kingdom at large; whence it follows that their estimates must be carefully examined by cultivators whose farms are differently circumstanced, or whose management is directed by more scientific principles in respect to the growth of turnip.

Culture.

The Cabbage requires a rich soil inclining to loam. The mode of cultivation greatly resembles that which proves most successful with potato, the plants being inserted along the summit of each ridgelet when there is a suitable depth of earth. The usual season is March, but they may be planted as late as June with every prospect of a fair crop in November; and on this account they are occasionally substituted for turnip, which has given way, either from want of rain or a defect in the seed.

Produce.

The produce is said to be from thirty-five to forty tons the acre; and Sir H. Davy found that 1000 parts of cabbage gave 73 of nutritive matter, of which 41 were mucilage, 24 sugar, and 8 gluten.

Rape.

Rape has of late years claimed for itself a place in the catalogue of field productions; being found valuable not only for the oil which is expressed from it, but also for feeding sheep on land not well adapted to turnip. It is cultivated on a variety of soils, as a first crop after paring and burning, and when old grass-lands are brought into tillage. Upon fields kept under the plough it comes into the rotation as a green crop; and the preparation and after culture are the same as for turnip. A variety of this plant is extensively cultivated in Flanders chiefly for the sake of the oil expressed from its seed. The husks in the form of cake or dust, after the oil is withdrawn, constitute an important manure, to which we have already invited the attention of the reader. The following remarks by the late Mr. Culley of Northumberland, comprehend all that are necessary to be said on this subject.

Mr. Culley's Remarks.

"Rape may be sown from the 24th of May to the 8th of June, but comes to the greatest growth if sown in May. If sown earlier, it is apt to run to seed. From two to three pounds of seed is required per acre sown by a common turnip-seed drill. But as Rape-seed is so much larger than turnip-seed, the drill should be wider. When hoed, the Rape should be set out at the same distance as turnip plants. The drills should be from 26 to 28 or 30 inches, according to the quantity of dung given. As many ploughings, harrowings, and rollings should be given as may be necessary to make the soil as fine as possible; the produce will be from twenty-five to fifty tons or upwards. But it is not so much the value of the green crop, as the great certainty of a valuable crop of wheat that merits attention. The sheep are put on from the beginning to the middle of August; they must have the Rape consumed by the middle, or at latest by the end of September, so that the wheat may be sown before the Autumnal rains take place. The Burwell red wheat is always preferred. The land must be made as clean as any naked fallow. There is scarcely an instance known of a crop of wheat sown after Rape and eaten off with sheep being mildewed; and the grain is generally well perfected."

Clover.

In the modern scheme of cultivation by rotation of crops, *Clover* enters into the regular succession. Before it was introduced, it was thought necessary whenever land was exhausted by grain crops, to leave it in a state of nature and inactivity for several years; after which it was again put under the plough. At present, however, such a miserable expedient is superseded by the practice of raising green crops and corn crops in a certain order on rich soils; while in regard to poorer lands, which do not permit so close a succession, Clover is useful as the means of converting them into excellent pasture.

Varieties.

Red clover, or, as it is sometimes called, broad clover, is the species most commonly grown on fields which bear an alternation of white and green crops, because it yields a larger produce for one year than any of the other sorts. The white or yellow varieties are seldom mixed with it, unless it be the intention of the farmer to lay down his ground in pasturage.

Culture.

On rich, clean soils ten or twelve pounds are sufficient for the acre, but on less fertile soils, especially of a stiff quality, sixteen or eighteen pounds are required. When it is to be cut for hay, thin sowing is recommended. It may be put in during any of the Spring months, with the new corn, or among young wheat. When it is cultivated with a drill crop, it is sown broad-cast, as soon as the grain is drilled, and covered in with a slight harrowing. Sometimes it is sown before the roller, when the barley is a few inches high; and sometimes it is introduced during the operation of hoeing, whether with the hand or by means of the horse apparatus. When the field is intended for early pasturage, it is usual in some districts to sow ray, rib, and similar grasses with the Clover; and in this way a more luxuriant herbage is produced, especially on the later kinds of soil; but when the crop is to be cut green, it is better to sow the Clover unmixed.

Cut while growing.

It is admitted that the greatest advantage is derived from this crop by cutting it in the green state, for feeding horses and cattle. Applied in this way, it is asserted that the Clover supports more than twice the quantity of stock, than by pasturing or feeding off in the field; and the additional manure thereby obtained is an ample compensation for the expense of cutting and carriage. Mr. Kent states the difference in the following terms. "The quick growth of this grass after mowing, shades the ground, and prevents the sun from exhaling the moisture of the land so much as it would if fed bare; consequently, it continues to spring with more vigour, and the moment one crop is off another begins to shoot up. Whereas when cattle feed it, they frequently destroy almost as much as they eat; and besides bruise the necks of the roots with their feet, which prevents the Clover from springing so freely as after a clean cut by the scythe. In hot weather, which is the common season for feeding Clover, the flies too are generally so troublesome to the cattle, that they are continually running from hedge to hedge to brush them off; by which it is inconceivable what injury they do to the crop. But when they are fed in stables and yards, they are more in the shade, they thrive better, and at the same time consume the whole of what is given to them without waste.

Agriculture. Seed clover.

When clover is intended to produce seed, it is sometimes cut for a first crop of hay, and the seed is obtained from the second crop; but it is a better practice to eat it well down in the early part of the Spring by ewes and lambs, for in this way the land is less exhausted, besides having afforded the peculiar advantage of early green food for the live stock. The crop remains till the husks or blossoms become quite brown, and the seeds have acquired firmness. After being cut down it is left on the field till it is dry and crisp, that the seeds may be fully hardened. It is then put up, and the seed is threshed out in the course of the Winter; a process which might be successfully managed by the application of a mill or other machinery.

Rye-grass with clover.

It is usual to sow rye-grass with clover, whether the land be meant for hay or pasture; the former commonly at the rate of a bushel the acre, or a smaller quantity if the soil be fertile and in good order. It may be of either the annual or perennial variety, if it be understood that the herbage is to be continued for only one year; and the former produces in general the more bulky crop.

Choice of seeds.

In the selection of both these seeds, particular attention should be paid to their quality and cleanness. The purple colour of the clover denotes that it has been ripe and well saved, and the seeds of weeds, if there be any, will be the more readily detected. Red clover from Holland and France has been found to die out in the season immediately after it has been cut or pastured; while the English seed produces plants which stand over the second, and even the third year. Between the seeds of the annual and perennial rye-grass the difference is hardly discernible; and therefore unless it be of his own growth, the farmer can have no certainty that he does not labour under deception in this important matter.

Trefoil

Trefoil is not only a useful plant in pasture lands, but may also be beneficially employed as one of the cultivated grasses. The stem is more slender, and the growth less luxuriant than common clover. It is sown with oats, or among the wheat crop in the Spring, when it is to be succeeded by grain in the following season; by which means a good feed is obtained for cattle from harvest till the dead of Winter. Trefoil affords good pasturage for all kinds of stock, but more especially for sheep. It is earlier than clover, and comes well in after the turnip and rye crops are consumed.

Sainfoin.

Sainfoin also is a very useful plant, especially on the lighter descriptions of calcareous soils; affording a valuable food in hilly situations, whether as hay or pasturage. It is sown with many of the Spring corn crops, but it thrives best with barley after turnip; and it is recommended by some that only half the quantity of barley used for a full crop should be used in such circumstances. Much of the success in all cases, however, depends on the after management. While some writers advise that it should be cut for hay instead of being pastured; others maintain that it should be neither cut nor pastured till the Autumn of the first year. The diversity of practice here recommended may arise from a difference of the soil, and a greater or less degree of luxuriance in the crop. But in every instance, a crop of hay is taken the succeeding Summer; and the after-grass is fed down, to a certain degree, by any kind of stock except sheep till the month of December.

Its culture.

It is not till the third year that Sainfoin attains its perfect growth; and it begins to decline about the eighth or tenth, unless manure be liberally applied. Coal-ashes, peat-ashes, soot, and malt-dust are employed for this purpose; and when the plants are well established in the soil, top-dressings of this kind, every third or fourth year, retain them in vigour nearly double the period. This crop is useful in its green state for all kinds of stock, although it has been supposed that the flavour of milk is injured by it; but it is more commonly used as hay, as it affords a very nutritious food to working horses as well as other descriptions of cattle.

Lucerne.

Lucerne has for a good many years occupied a part of our best cultivated lands. It grows most luxuriantly on deep, rich, loamy soils, which must, however, be kept dry and well manured. With this view the fields are prepared either by means of fallowing, or by a hoed crop of turnips, carrots, or cabbages. The plants strike deep into the ground, sending up numerous clover-like shoots, which bear blue or violet-coloured leaves. It is extensively grown in the South of Europe, and has been found to answer well in many parts of England, though the principal seat of its culture is Kent. The Roman authors extol this grass very highly and give minute directions for its management; reminding the practical farmer that it requires a deep, friable soil inclining to sand with a subsoil of a similar character; that it must be sown early in the season; kept free from weeds; and occasionally supplied with a top-dressing of manure.

Sowing Lucerne

The seed of Lucerne is of a larger size and paler colour than that of clover. The quantity required in the broad-cast method is from eighteen to twenty pounds per acre; but when drilled in rows twelve inches distant, ten or twelve pounds are said to be sufficient, though our own experience, even on good land, confirms us in the belief that this estimate is rather too low. When the plants are to be raised in a seed-bed, the sowing should be as early as the frosts admit, that they may be fit for transplanting in August. This mode can only be practised on a limited scale, and in order that where the soil is rich the crop may stand thin and regular, and thereby acquire a vigorous growth. Where the labour of weeding and hoeing cannot be perfectly executed, the broad-cast method of sowing may be adopted; but where suitable attention to the land can be bestowed, drilling at narrow distances should unquestionably be preferred.

with other crops.

In a fertile country, there is an obvious advantage in sowing the Lucerne alone, inasmuch as less time is lost, while there is a greater certainty of obtaining a crop. But the sowing with corn on light and porous soils affords the young plants some protection, and also, it is thought, prevents the ravages of the fly. When Lucerne is sown with grain, the quanty of seed used for the latter ought to be smaller than for a separate crop; and we add that for this purpose oats are considered better than barley as they are not so apt to lodge in a moist season.

Culture.

The culture of Lucerne is attended with considerable expense, but, when it succeeds, it brings to the farmer a full remuneration. Being one of the earliest grasses, it is sometimes ready for the scythe about the end of May, and, in favourable soils, it may be cut every five or six weeks throughout the season. Again, besides affording a very nutritious food, it is extremely useful for soiling horses and other cattle, and indeed for all the purposes contemplated by the Agriculturist in raising the artificial grasses. The failure of clover in lands whereon it

Agriculture.

has been too frequently grown, a fact fully established by experience, may therefore induce practical men to make a trial of Lucerne in places in which it is hitherto little known; and in time it may possibly become so inured to our climate as to grow luxuriantly in parts of the Island, of which the soil and climate do not rank in the first class. It is sometimes used for hay; but unquestionably the most profitable application of it is in its green state, for the soiling and feeding of live stock.

Flax and Hemp.

As Flax and Hemp are very sparingly grown in this Country, we shall hold it sufficient to mention that they both require good soils, and are, at the same time, considered so exhausting to the land as to require a larger price than can be obtained in face of a competition with Holland and Russia. Dutch seed is in higher estimation than any other; it being found that it raises a larger produce than the American, and secures a finer quality than that imported from Riga. In former times the process of steeping and bleaching was both tedious and precarious, for if the weather became wet there was a great risk of losing the whole crop before it could be dried; but this labour and hazard are now precluded by the use of Hill and Bundy's Patent machines, by which the whole preparation of Flax for the mill may be accomplished in the space of six days.

Hops.

The Hop, though largely cultivated in some parts of the Kingdom, is by no means a general product of Agricultural labour throughout the Empire, because it requires advantages of soil and climate which are denied to the greater portion of it. In the most favourable situations it is a very precarious crop, sometimes yielding an ample profit, and at other times not defraying the expense of rearing it. The plant itself, as Mr. Parkinson remarks, is extremely liable to disasters, from its first putting up in the Spring until the time of picking in September. Snails and slugs, ants and fleas, are formidable enemies in the first instance. Frosts are inimical to its growth; and the bines are frequently blighted even after they have reached the top of the poles. Certain green flies which make their appearance in the months of May and June, when the wind is about North-East, often greatly injure them; and they are subject to be damaged by high winds from the South-West. The best situation therefore for a hop-garden is a Southern aspect, well shaded on three sides, either by hills or planting, which is supposed to be the chief protection that can be given them.

Culture.

When it is intended to have a new plantation, the best method is to have the cuttings from approved stock planted out the year before they are wanted in the hop-ground, as the use of plants instead of cuttings not only gains twelvemonths, but they are more certain to flourish, as many of the latter will not take root in a dry season. A small piece of moist land is sufficient to raise plants for many acres and at little expense. In preparing the ground, it is worked with a spade, and set out in ridges about ten feet wide, and two yards between each; having a strip of grass, called a pillar, next every ridge, and an open drain between every two pillars, the depth of which varies according to the soil. Three rows of plants are made upon each ridge, which should intersect each other at right angles. They are generally about six feet distant in the rows, so that the number of plants on a statute acre may be estimated at thirteen hundred.

Expense.

The expense of taking up hop ground is from £5 to £6 per acre, as the price of planting varies with the mode pursued; and if the drains are required to be deep or the soil is particularly strong, a still greater sum will be expended; to which may be added £25 per acre for poles, the rent and taxes, and also the working for three years before many hops can be expected. "The following are termed the annual orders: digging the ground completely over, hoeing the earth from the plants, and cutting off the stock a little above the roots, which processes are called *pickling* and *cutting*; *poling*, which is carrying the poles from the stacks, and setting them down to the plants with a round implement shod with iron and called a *poy*, having a crutch at the top and a peg through the middle to tread upon; tying the bines round the poles with rushes and pulling up the superfluous bines; hoeing the ground all over with a hoe of large dimensions; wheeling and laying manure upon every plant or hill; covering the manure with the soil, which is done by scraping the ground over with a hoe and is called *hilling*; and *stacking*, which is carrying and setting up the poles into heaps or stacks, after the crop has been taken. The annual expense of these orders varies from £2. 15*s.* to £3. 5*s.* per acre.

Manure.

As to the manure most proper for the hop culture, good stable dung is much used, and is preferred to the manure made by cattle, as the latter encourages ants on strong ground. Woollen rags are the best for forcing a luxurious bine, and if used with judgment are excellent for clay-land; but they are apt to make the hops small if too many are employed. Malt, culm, and dove-manure are excellent; and one complete dressing with lime is very serviceable for strong ground.

Picking, &c.

When the crop is ripe, a proper number of pickers are procured, for whom are provided light wooden frames, called *binges*; they are clothed with hop-bagging, into which the hops are picked off the poles by women and children, having them brought by men, who take them up by cutting the bines about a foot above the ground, and drawing up the poles by an instrument called a *dragon*. Each *binge* has from four to six pickers, and a man attends to one or two *binges* according to the crop; he strips the bines from the poles as they are picked and lays them in heaps ready for stacking; he also carries the hops to the kilns, if near, or to a cart, as they are measured from the *binge*. It is necessary to have a supply of coke in the kilns to dry the hops which are spread on hair-cloth, stretched upon an open floor of wood over the fire, every noon and midnight, so long as the picking continues. They are stirred repeatedly, and when cured are turned off into the store-room to be put into bags and pockets, (after they have been there about a week,) which is done by fixing each bag in a frame and treading the hops in. The excise officer, who attends during the season, then weighs them, and charges twopence per pound for the duty, when they become marketable.

Profits.

From the foregoing particulars, continues Mr. Parkinson, it will appear that there are scarcely any hop-grounds which do not cost yearly upwards of £12 per acre, (exclusive of the picking and duty, which may exceed £20 per acre;) and there are other grounds on which upwards of £20 the acre are expended; so the average may be said to be about £15 per acre, without the picking, drying, and duty. If a good plantation produces ten hundred weight per acre in a crop year, which are sold at £5 per hundred weight, the annual expenses being £20, and the labour and duty £20, the profit will be £10; and admitting that the same ground pays

Agriculture. all expenses in a blight year, and supposing this to be every third year, the profits would be nearly £7 per acre annually. But, as the foregoing crop cannot be expected on any ground every other year, the produce of the third year may be stated at five hundred weight per acre, at eight guineas per hundred weight; from which amount must be deducted the annual expenses £20, and the picking and duty £12, leaving as before a profit of about £10.

On a suitable soil, properly managed, a hop plantation may continue in a state of tolerable productiveness, fifteen years or more, but in ordinary circumstances it begins to deteriorate about the tenth year. The expense of forming one has been estimated, including all the expenses of cultivation and building, at from £70 to £100 per acre. The annual dressing, too, absorbs a great quantity of manure, which, of course, must be withheld from the lands under tillage, and thereby give occasion to a certain degree of loss. It may consequently be inferred that the growing of hops, in favourable circumstances of soil and climate, is a profitable application of agricultural capital and skill.

Other crops. Our limits will not permit any minute description of a variety of other productions which, in particular districts, occupy the attention of the farmer: such as *fiorin grass*, strongly recommended by the late Dr. Richardson; *woad* and *weld*, articles used for dyeing black and yellow respectively; the *spurry*, or *Spergula arvensis*, a plant occasionally sown on stubble fields; *buck-wheat*, a grain principally used for feeding poultry; *maize* or Indian corn, lately attempted on a small scale; and *kelp*, a marine product raised for the purpose of supplying an alkali or potash, which is found useful both as a manure and in the manufacture of soap and glass. We therefore pass on to another branch of our subject, namely,

The Succession or Rotation of Crops.

Causes of fertility. It is now one of the best established principles in farming, that land from which the same species of crop is taken for a number of years, is more exhausted than if the same quantity of produce were raised from it, provided the grain or plants were of different sorts. Hence it is an important inquiry, how the kinds of crop best adapted to different situations should be selected, so as to obtain at the cheapest rate, and with the most certain success, those which are the most advantageous and which best correspond with the nature of the land and the husbandman's means of raising them; keeping in view general economy and profit, and the full supply of manure requisite to support the fertility of the soil. In every system of management, a remark made by Dr. Coventry, the late Professor of Agriculture at Edinburgh, should be remembered; namely, that the fertility of any soil is augmented in proportion as it is already fertile; or, in other words, that it is more difficult to raise the fertility of land from the pitch of bearing two quarters to that of three, than from three to five or even six. It is true, as the same author observes, that the circumstances of situation can alone determine what are the most proper species of crops for culture, the proportion in which they should be raised, and the best order or succession with respect to one another. Certain particulars in different cases require the attentive consideration of the husbandman, when about to settle the mode of culture for his arable fields; some of them are of general import while others are more connected with local peculiarities of earth and atmosphere. Agriculture.

Alternate In all cases, the main points to be considered are the proper adaptation of the corn crops to the nature and state of the lands, and the judicious intermixture of green crops so as to prevent the exhaustion or deterioration of the soil; that is, the strict observance of the alternate husbandry. In this way the culture of the field approaches to that of the garden, and the impoverishing effects produced by a succession of grain crops are avoided, while the amount of produce is greatly increased. But it ought to be observed that the fertility even of the richest land cannot be retained by a constant course of alternate cropping; while such management on a sandy soil, and indeed on all of a higher description, is positively injurious. For the purpose of keeping up the requisite degree of vigour in such lands, that portion which has produced a herbage crop is allowed to remain in pasture, during one or two years. According to this system, which, to distinguish it from the alternate, is denominated *convertible* husbandry, the same land is at one period under the plough, and at another in pasture grass. In conducting both schemes, the convertible and the alternate, the farmer must not repeat a crop on the same field at too short an interval; and this remark applies to turnip and potato as well as to wheat or rye. A too rapid recurrence is certain to be followed by a diminution in the extent as well as in the quality of the produce. and convertible crops.

It has been recommended by the author of the *Survey of Middlesex*, that where the land is of the best quality an alternation of green and white crops may be pursued; that where the land is of a full medium quality, three green crops and two corn crops should be taken; that for ordinary land the proportion should not exceed one corn crop for two green crops; and that for poor exhausted land, as that of the Down and Sheep-Walk description, one grain crop is sufficient for three of potato, clover, or turnip. By cropping in this manner and in the proportions now stated, it is supposed that lands may be kept in a clean state and in a proper degree of fertility; or as the author expresses it, under such management they might be continued in perpetual aration with a constant succession of large products. Proportion of green and white crops.

According to the proportions just stated, the following series of crops are suggested: Rotations.

I. Corn, clover, peas; or peas, beans, corn; being two green crops for one of the white kind.
II. Corn, clover, tares, turnips; or corn, clover, peas, and beans; being three green crops to one white.
III. Tares, potatoes or cole, turnips, corn, clover; being four green crops to one of corn.
IV. Peas, beans, corn, clover, tares, turnips; being five green crops to one of grain.

On lands where the convertible husbandry is pursued, horse-hoeing practised, and the green crops sown on ridges at a proper distance from one another, the following Rotations are suggested by Mr. Close for different sorts.

I. On clay soils.
1. Turnips or cabbages.
2. Oats.
3. Beans and clover.
4. Wheat.
5. Turnips or cabbages.
6. Oats.
7. Beans and vetches.
8. Wheat.

II. On clayey loams.
1. Turnips or cabbages.
2. Oats.
3. Clover.
4. Wheat.
5. Turnips or cabbages.
6. Barley.
7. Beans.
8. Wheat.

III. On rich or sandy loams.
1. Turnips and potatoes.
2. Barley.
3. Clover.
4. Wheat.
5. Beans.
6. Barley.
7. Peas.
8. Wheat.

IV. On peaty soils.
1. Turnips.
2. Barley.
3. Clover.
4. Wheat.
5. Potatoes.
6. Barley.
7. Peas.
8. Wheat.

V. On a chalky subsoil.
1. Turnips.
2. Barley.
3. Clover.
4. Wheat.
5. Potatoes.
6. Barley.
7. Peas.
8. Wheat.

VI. On gravelly soils.
1. Turnip.
2. Barley.
3. Clover.
4. Wheat.
5. Potatoes.
6. Barley.
7. Peas.

VII. On light lands.
1. Turnips.
2. Barley.
3. Clover and rye-grass.
4. Ditto, ditto.
5. Ditto, ditto.
6. Peas.
7. Rye.
8. Wheat.

Cross-cropping.

These examples are sufficient to illustrate the subject of improved Rotations as explained by Mr. Brown in his *Treatise on Rural Affairs*, but as the best general scheme may be occasionally deviated from with advantage, the same author adds that cross-cropping in some cases may perhaps be justifiable in practice. For instance, we have seen wheat taken after oats with great success when these last had followed clover on a rich soil, though, as a permanent rule, it cannot be recommended. We have heard of another Rotation which seems to come under the same predicament, were it not that, without the test of experience, we must not presume to pronounce upon its merits. The method alluded to begins with a naked fallow, and is carried on with wheat, grass for one year or more, oats, and wheat again, with which the series terminates. The supporters of this plan of cultivation maintain that beans are an uncertain crop and raised at great expense; and that in no other way will corn, in equal quantity and of equal value, be produced at so little expense. That the cost is lessened we readily admit, because no more than seven ploughings are given through the whole Rotation; but whether the crops will be of equal value, and whether the ground will be preserved in equally good condition, are points which remain to be ascertained by experience.

Expense.

Rotations in East Lothian.

In East Lothian, a district in which Agriculture has reached a high degree of perfection, the following Rotations are observed. On lands near the sea where the soil is a dry gravelly loam, a four-course shift, as they call it, is adopted. 1. Turnip with or without manure; 2. barley or Spring-wheat with grass seeds; 3. clover, used green for cattle, or cut for hay; 4. wheat, or oats if wheat was taken before, manured on the clover lay. On this description of land, the turnips are consumed on the ground by sheep. On deeper loams with a dry bottom the usual Rotation is, 1. turnips; 2. barley or spring wheat; 3. grass; 4. oats; 5. beans drilled and horse-hoed; 6. wheat. The manure is applied only once, and in this Rotation is given to the turnip, so that success in this mode of cultivation can be obtained only on land of the best quality. On heavy loams with a retentive subsoil the method is somewhat different; namely, 1. fallow with manure; 2. wheat; 3. beans drilled and horse-hoed; 4. barley; 5. clover, which is manured on the stubble; 6. oats; 7. beans; 8. wheat. The application of manure twice in the course of this Rotation is found very beneficial.

Varieties of the same grain.

Connected with Rotation we may observe that a change of the *variety* as well as of the *species* of the plants used in husbandry, is found to be attended with great advantage. It is well known that of two parcels of wheat, for example, as much alike in quality as possible, the one which had been raised on a soil differing much from that on which it is to be sown, will yield a better produce than the other that grew in the same, or in a very similar soil and climate. Thus farmers too, in one district find that wheat from another, although not superior to their own, is a very advantageous change; while oats and other grain brought from a clayey to a sandy soil, are more productive than seed raised on similar ground.

Distribution of crops.

No precise rules can be laid down for fixing the proportion of any farm which should be occupied by the different crops; for the quantity of land destined to each must be varied not only according to its soil and climate, but even according to its local situation in regard to markets. As, however, a great object in every well-regulated system of husbandry is to preserve the ground in good condition, and at the same time to derive from it the greatest quantity of produce it is capable of yielding, a certain relation must always be established between the extent of land allotted to green crops on the one hand and to corn crops on the other. The necessity of this arrangement will appear from the fact that, while the return of manure from corn is only about four tons for the acre, the amount arising from a green crop exceeds six tons; and, as it has been calculated that a farm cannot be kept at the proper pitch of fertility, unless the crop yield manure at the average of five tons, it becomes manifest that a given proportion of the land must be used for the production of turnip, clover, and potato.

Experiments on Soils and Manures.

Before we conclude this branch of the subject we shall add a few remarks on the advantage of experiments on soils and manures, made with the view of ascertaining

their influence on each other, and their respective tendency to invigorate the principles of fertility, and increase the amount of Agricultural produce. Here we do not allude merely to those trials made by theorists and speculative writers on the Geological properties of soil at large, nor to those ingenious conclusions derived by the Chemist from a scientific analysis of the various substances which are applied for its improvement in the great scale. We rather mean those particular experiments which are made by individuals on their own lands, with a reference to the several kinds of manure which may happen to be within their reach. Were this plan generally adopted by farmers, a degree of precision and accuracy in their knowledge of rural affairs would soon be acquired; which, we venture to predict, would place Agriculture as far in advance of what it is at present, as it is now in advance of what it was fifty or eighty years ago. The trouble and expense of making experiments is, no doubt, considerable; but the value of the knowledge thereby obtained would prove an ample remuneration, preventing much useless labour and an unprofitable outlay of capital.

by Mr. Oliver.

To illustrate what we mean we shall give an example of the kind of experiment now recommended, supplied to us by an eminent Agriculturist in Mid Lothian.* The object in view was to ascertain, in the first place, the relative value, in producing potatoes, of dry recent horse-manure, of cow-dung, and of street-sweepings, or rather the aggregate substances which are collected in large towns under the direction of the police; and secondly, that particular distance between the rows in a field of potatoes which will secure at once the largest produce and the best quality.

For this purpose a portion of land was selected, as nearly as possible of a uniform character, and extending to about two Scotch acres. The plan of proceeding will be easily understood by the subjoined description of the field. It was divided into five portions of thirty-six feet broad; each of which again divided into three portions twelve feet broad. Upon the first twelve feet, beginning at one side of the field, twelve drills, occupying one foot each, were formed, and cow-manure applied at the rate of forty carts, weighing about eighteen hundred weight each, to the acre. Upon the second twelve feet twelve drills of the same width were made, to which the same quantity of dry horse-manure was applied; and on the third twelve feet, the like quantity of street-manure was laid, and the same number of drills were planted. In like manner, upon the remaining four divisions of thirty-six feet, drills at the distance of eighteen, twenty-four, thirty, and thirty-six inches respectively were formed, and the same kinds and quantities of manure were applied in the same order; that is, on every separate portion of thirty-six feet, subdivided into three sections of twelve feet, cow-dung, horse-dung, and street-dung were laid successively as has just been described.

The whole field was planted with that description of potato known in Scotland by the name of *Dons*, and in England by that of *Pinkeyes*. It is obvious that there were in it fifteen lots or portions; each of the five principal sections being subdivided into three minor sections. When the crop was ripe, each division was lifted separately, the produce freed from earth by riddling, and carefully weighed. In order to ascertain the effect of the different widths on quantity, the weight obtained from each of the five divisions on which drills of twelve, eighteen, twenty-four, thirty, and thirty-six inches respectively were formed, was ascertained. For this purpose it will be observed, it was not necessary to make any distinction as to the different kinds of manure applied, because each division received an equal portion of the three sorts.

The result as to the effect of distance between the drills is exhibited in the Ist Table, and goes far to prove the importance of attending to that particular.

The IId Table exhibits the result of the experiment as to the relative value of the several kinds of manure employed; which, taken in connection with various other experiments on the same subject, leaves no doubt that great benefits would arise from experimental investigations in regard to the means of fertilizing land for different species of crops. It is rendered manifest on the present occasion, that street-manure is very inferior, for the purpose of cultivating potatoes, to that supplied either by the cow or horse; but no general conclusion can be established until it shall be verified by experiments that its inferiority is equally great on all other soils. The ascertainment of this simple fact might perhaps lead to the most important results as to the peculiar food, or *pabulum*, of the potato plant.

The IIId Table is formed by taking the average produce per acre, obtained from each of the three kinds of manure employed, and at the several distances between the rows, as shown in Table II. In this way is brought into one view the comparative values of the manures and the average result of the five experiments. In fact, each of the five greater divisions may be regarded as a separate illustration of the principles involved, whether in the mode or material of cultivation; though when the whole are alternated and repeated under so great a variety of circumstances, they produce a greater degree of confidence than when estimated singly. But we beg the attention of the reader to the Tables themselves.

* Mr. Oliver, who through the medium of the Periodical Press has thrown much light on some interesting branches of rural economy.

Agriculture. Agriculture.

Sketch of the Field showing the situation of the Lots, their Produce, and the manner in which the different kinds of Manure were applied.

Measurement. A.	R.	P.	Inches between rows.					Bolls.	F.	P.	
0	1	$5\frac{3}{4}$	12	Cow-dung	12 Rows	$15\frac{1}{4}$ Falls	Produce	4	0	0	36 feet.
				Horse-dung	12 Rows	$15\frac{1}{4}$ Falls	Produce	4	3	0	
				Street-dung	12 Rows	$15\frac{1}{4}$ Falls	Produce	4	0	0	
0	1	$7\frac{3}{4}$	18	Cow-dung	8 Rows	16 Falls	Produce	6	0	0	36 feet.
				Horse-dung	8 Rows	16 Falls	Produce	5	3	0	
				Street-dung	8 Rows	16 Falls	Produce	4	2	0	
0	1	10	24	Cow-dung	6 Rows	$16\frac{2}{3}$ Falls	Produce	6	1	2	36 feet.
				Horse-dung	6 Rows	$16\frac{2}{3}$ Falls	Produce	6	1	1	
				Street-dung	6 Rows	$16\frac{2}{3}$ Falls	Produce	4	0	1	
0	1	$10\frac{3}{4}$	30	Cow-dung	5 Rows	18 Falls	Produce	7	2	0	36 feet.
				Horse-dung	5 Rows	18 Falls	Produce	7	2	0	
				Street-dung	5 Rows	18 Falls	Produce	4	1	0	
0	1	$8\frac{3}{4}$	36	Cow-dung	4 Rows	$17\frac{1}{4}$ Falls	Produce	6	3	1	36 feet.
				Horse-dung	4 Rows	$14\frac{1}{4}$ Falls	Produce	6	0	2	
				Street-dung	4 Rows	17 Falls	Produce	5	0	0	

TABLE I.

Showing the Profit or Loss upon raising Potatoes at 12, 18, 24, 30, and 36 inches between the Rows.

Distance between rows.	Quantity of ground in each lot.			Produce.				Quantity per acre.				Price per boll.	Value per acre.			Cost of production.			Loss per acre.			Profit per acre.		
Inches.	AC.	R.	P.	B.	F.	P.	L.	B.	F.	P.	L.	s.	£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.
12	0	1	$5\frac{3}{4}$	12	2	0	0	43	2	3	1	8	17	9	$7\frac{1}{2}$	24	8	0	6	18	$4\frac{1}{2}$	......		
18	0	1	$7\frac{3}{4}$	16	1	0	0	54	1	3	0	8	21	15	6	23	8	0	1	12	6	......		
24	0	1	10	16	3	0	0	53	2	1	2	8	21	8	9	23	0	0	1	11	3	......		
30	0	1	$10\frac{3}{4}$	19	1	0	0	60	2	3	0	8	24	5	6	22	13	0	......			1	12	6
36	0	1	$8\frac{3}{4}$	17	3	3	0	58	3	2	0	8	23	11	0	22	10	0	......			1	1	0

TABLE II.

and Street-dung, each applied at the rate of Forty Carts per Acre.

Distance between rows.	Kinds of manure applied.	Produce per acre.	Value per boll.	Value per acre.	Cost of production.	Price of manure per cart.	Loss per acre.	Profit per acre.
		B. F. P. L.	s.	£. s. d.	£ s. d.	s d.	£. s. d.	£. s d.
12	Cow.	42 0 0 0	8	16 16 0	25 8 0	4 0	8 12 0	....
	Horse.	47 0 3 0	8	18 17 6	23 8 0	3 0	4 10 6	....
	Street.	42 0 0 0	8	16 16 0	24 8 0	3 6	7 12 0	....
18	Cow.	60 0 0 0	8	24 0 0	24 8 0	4 0	0 8 0	....
	Horse.	51 2 6 0	8	23 0 0	22 8 0	3 0	......	0 12 0
	Street.	45 0 0 0	8	18 0 0	23 8 0	3 6	5 8 0	....
24	Cow.	61 0 3 0	8	24 9 6	24 0 0	4 0	......	0 9 6
	Horse.	60 1 0 0	8	24 2 0	22 0 0	3 0	......	2 2 0
	Street.	39 0 0 0	8	15 12 0	23 0 0	3 6	7 8 0	....
30	Cow.	66 2 2 0	8	26 13 0	23 13 0	4 0	......	3 0 0
	Horse.	66 2 2 0	8	26 13 6	21 13 0	3 0	......	5 0 0
	Street.	46 3 2 0	8	18 15 0	22 13 0	3 6	3 18 0	....
36	Cow.	63 0 3 0	8	25 5 6	23 10 0	4 0	......	1 15 6
	Horse.	67 2 2 1	8	27 0 7½	21 10 0	3 0	......	5 10 7½
	Street.	47 0 0 0	8	18 16 0	22 10 0	3 6	3 4 0	....

TABLE III.

Showing the average Profit or Loss upon Potatoes raised at the Distances between the Rows and with the three kinds of Manure in TABLE II.

Kinds of manure.	Bolls per acre.	Price per boll.	Value per acre.	Cost of production.	Loss per acre.	Profit per acre.
	B. F. P. L.	s.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Cow.	58 2 1 2	8	23 8 9	24 3 9½	0 15 0½	....
Horse.	59 3 1 1	8	23 18 7½	22 3 9½	....	1 14 10
Street.	43 3 3 3	8	17 11 10½	23 3 9½	5 11 11	....

Results. Width of Drills.

From the Ist of these Tables it appears that the distance of thirty inches between the drills ought to be preferred to any of the others; there being uniformly a loss on all the portions grown at narrower intervals, and the greatest on that where the drills were only twelve inches apart. It appears, at the same time, that a greater width would not prove beneficial; for the piece of ground where the drills were at the distance of thirty-six inches was not equally productive with that on which they were only thirty inches separated; the profit on the latter being £1. 12*s*. 6*d*., whereas on the former it was only £1. 1*s*.

Comparative goodness of manure.

From the IId Table it is manifest that dry recent horse-manure is decidedly preferable to either of the other two, the loss with it on drills of twelve inches being considerably less than with the cow or street-dung: while in drills at all the other distances, it yields by far the largest profit. It further results from the facts detailed in this Table that street-manure should not be used in growing potatoes where either of the others can be procured; and on the whole it is rendered too clear to admit of any doubt in the mind of a practical Agriculturist, that the width between the rows and the kind of manure applied are objects of the greatest importance in the management of this particular crop.

On Potato Crops.

From weighing the foregoing facts it might be inferred that the growing of potatoes, even with the largest profit which appears attainable, is not an object worthy of much attention. It is admitted that the profit is very small, but it ought to be kept in mind that, at certain intervals, the land must receive a supply of manure, in order to compensate for the exhaustion occasioned by a succession of corn crops. It is equally necessary, too, that the soil shall be well pulverized and completely cleared from all root weeds; and these operations can be performed to advantage only when the field is subjected to a Summer-fallow, or cropped with drilled potatoes or turnips. Besides, in estimating on the cost

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of production in the foregoing Tables we have charged the crop with the whole cost of manure together with the expense of sufficiently pulverizing the ground so as to warrant the expectation of at least three good crops without any more dung, or much outlay on the process of clearing. On grounds of a moderately light texture, potatoes are a better preparation for wheat than Summer-fallowing; and hence whatever profit is gained by the green crop ought to be regarded as in some measure, a gratuitous addition to the farmer's capital.

CHAPTER II.

On Live Stock.

Divisions of the subject.

We have already remarked that Rural Economy divides itself into two great heads: first, the cultivation of the soil for vegetable productions; and, secondly, for the rearing of live stock. This last is naturally separated into three parts, as it respects the objects which are kept in view in the breeding of cattle, whether for labour, the butcher-market, or the dairy. According to the order thus suggested, therefore, we shall arrange our observations on the subjects which are usually comprehended under the title placed at the head of this Chapter.

Animals for labour. The Horse.

On many accounts, the Horse deserves to stand at the head of domestic animals. Viewed as the assistant of Man in the labours of the field, he is chiefly valued for his strength, activity, and hardiness. Mr. Culling, whose Work *On Live Stock* is greatly esteemed, describes the Horse best fitted for Agricultural purposes in the following terms. "His head should be small as the proportion of the animal will admit; his nostrils expanded and muzzle fine; his eyes cheerful and prominent; his ears small, upright, and placed near each other; his neck rising out from between his shoulders with an easy tapering curve must join gracefully to the head; his shoulders being well thrown back, must also go into his neck, at what are called the points, unperceived; which, perhaps, facilitates the going more than the narrow shoulder; the arm, or fore thigh should be muscular, and tapering from the shoulder, meet with a fine, straight, sinewy, bony leg; the hoof circular, and wide at the heel; his chest deep and full at the girth; his loin or fillets broad and straight, and body round; his hips or hooks by no means wide, but quarters long, and tail set on so as to be nearly in the same right line as his back; his thighs strong and muscular; his legs clean and fine-boned; his leg bones not round, but what is called lathy or flat.

Welsh and Highland Ponies.

If we trace the lineage of this noble animal, we shall probably find the true type of his ancestors still existing in the ponies of Wales and Scotland. The Highland horse is sometimes only nine, and seldom twelve hands high, except in some parts of the Hebrides, where, by selection and better feeding, the size has been raised to thirteen or fourteen hands. The best of this breed are handsomely shaped, have small legs, large manes, little, neat heads, and are extremely active and hardy. The Welsh horse bears a near resemblance to the larger description of the Highland breed, and is still more remarkable for the power of enduring fatigue. The modern system of Agriculture, however, which has introduced almost everywhere the two-horsed plough, has gradually superseded all attention to the native species of the country. The Shetland pony, indeed, is sometimes reared as a curiosity, or for the use of children, but in no part of the Kingdom for the purposes of tillage. This ancient race is supposed to have been brought into Scotland from Scandinavia, when the Northmen first gained a footing in Caledonia; and it is precisely the same breed which subsists at present in Norway, the Feroe Isles, and Iceland, being totally distinct from all the varieties which are seen on the Continent of Europe Southward of the Baltic.

Dutch and German horses.

The main source of improvement in our farm horses may be traced to Holland and Germany, whence our Agriculturists at an early period imported a breed of heavy, large-boned animals, the parents of the finest and best working animals we at present possess, whether in the South or North. The *Suffolk Punch* is perhaps better suited than any other to the general purposes of rural labour; having a great deal of constitutional hardiness, combined with sufficient action for either the plough or the waggon. The colour, usually yellowish or sorrel, with a white-scratch or blaze on the face; the head large, ears wide, muzzle coarse, fore end low; back long, but very straight; sides flat; shoulders too far forward; hind-quarters rather high about the hips; legs round and short in the pasterns; deep-bellied and full in the flanks, a quality which enables him to retain his food long, and undergo without inconvenience a more protracted toil than a finer horse could endure.

Suffolk Punch.

Black Cart-horse.

The *Black Cart-horse*, so well known in most parts of England, and of which we see the most improved variety in the streets of London, is not so much esteemed by the farmer as by the drayman and the waggoner. He is heavy and sluggish, and by no means so capable of standing a long day's work as a much smaller animal of better blood. The *Cleveland Bays* are a more active and hardy race, though it is alleged, they are no longer so carefully reared as in former times. They are said to have drawn their best qualities from a cross with racers, and, consequently, to have turned out excellent hunters, good roadsters, and, at the same time, well fitted for the duties of our Cavalry regiments. In the Northern Counties, they are to be seen in a condition more or less improved, on almost every farm, both as plough-horses, and also as prepared for the market, where they are eagerly purchased by coachmasters and travellers.

Cleveland Bay.

Clydesdale horse.

The *Clydesdale horse* is in great repute in several Counties on both sides of the border, and for the uses of Agriculture he is probably equal to any other in Britain. He is larger than the *Suffolk Punch*, and the neck is somewhat longer; the colour is black, brown, or grey, and a white spot in the face is esteemed a mark of beauty. The breast is broad; the shoulder thick; the hoof round, usually of a black colour, and the heels wide; the back straight and broad, but not too long; the hucks visible, but not prominent, and the space between them and the ribs short; the tail heavy and well-haired; and the thighs full and muscular. He is in general very true to his work, and remarkably steady in the draught.

Into the minute points of breeding and rearing we cannot enter with any prospect of satisfying the professional reader, or even of gratifying the curiosity of such as may choose to study this subject solely for amusement. We therefore satisfy ourselves with a reference to the Works of Lawrence, Marshall, Culley, Parkinson, Clark,

Agriculture. Coventry, and to a volume lately published in the *Farmer's Series* of the *Library of Useful Knowledge*, where the most accurate information is given relative to every thing which respects the history and treatment of the Horse. Confining ourselves to the use of that animal for Agricultural labour, we may advert to the question which has been sometimes started among practical men, whether oxen might not be beneficially substituted for horses in all the ordinary processes of Husbandry. In point of economy, then, it has been maintained that the ox is decidedly preferable to the horse, for besides that he can be more cheaply fed, he may, after serving a few years as a labourer, be remitted to the stall and fed for the butcher. It is admitted, at the same time, that wherever a powerful and steady pull is required, the ox performs the work better than his rival, being more patient and equal in his movements, and proceeding generally at a slower step. On this account a plough drawn by oxen would be selected in preference to any other by the farmer who has tough swards to tear up, or very rough ground to cultivate; and for the same reason these animals are yoked in the threshing-machine, whenever it is of any consequence to have a sure and regulated motion communicated to it. But, on the other hand, the ox is nearly useless for all other kinds of farm labour. He is not suited to the cart or waggon even on our fields, and far less on our public roads. Besides, he cannot be stirred to any unwonted exertion, however urgent may be the wants of his master; for if he is pushed beyond his natural step, all his energies forsake him, and he either stands still or throws himself on the ground. In rude Ages, when only the coarser productions of the soil are in demand, the cultivator uses the animal which cost him least in rearing and feeding; but whenever the progress of civilization extends the variety of commodities required by the consumer, and gives a value to luxuries in proportion to the early season at which they can be obtained, he dismisses the slow-paced ox, and adopts in his stead the more energetic horse. This is the natural order of things as soon as green crops constitute an article in the regular course of farming. On the Continent, where oxen continued to be used a considerable time after they were generally superseded in Britain, the horse is now almost universally preferred. The French Agricultural Writers agree with those of Britain, in perceiving the many advantages which attend the employment of the latter. A more enlightened experience every day tends to confirm the choice; and in the course of a few years the labour of the ox will be altogether unknown, except in particular situations where the greater vivacity and swiftness of the horse might prove hazardous. We conclude this section by remarking that the care bestowed upon the keeping of the horse is always well repaid. The manure replaces the expense of litter; and his constant aptitude for work is an ample equivalent for the carrots, potatoes, and grain, which constitute his best food.

Comparison bet- horses and oxen.

Of Cattle.

There are now numerous varieties or breeds of cattle in Great Britain, but perhaps all of them may be traced more or less directly to that singular one which is still preserved as a curiosity in the parks of several Noblemen, more especially Lord Tankerville and the Duke of Hamilton. It is usually distinguished as the *wild*, or original breed, and has been described by Mr. Culley in the Work already mentioned. Their colour, says he, is invariably of a creamy white; muzzle black; the whole of the inside of the ear, and about one-third of the outside from the tips downward red; horns white with black tips, very fine, and bent upwards; some of the bulls have a thin, upright mane, about an inch and a half or two inches long. The weight of the oxen is from thirty-five to forty-five stone, and of the cows from twenty-five to thirty-five stone, the four quarters, fourteen pounds to the stone. At the first appearance of any person they set off in full gallop, and at the distance of about two hundred yards make a wheel round and come boldly up again, tossing their heads in a menacing manner. On a sudden they make a full stop at the distance of forty or fifty yards, looking wildly at the object of their surprise; but upon the least motion being made they all turn round and fly off with equal speed, but not to the same distance, forming a shorter circle, and again returning with a bolder and more threatening aspect than before. This time they approach much nearer, probably within thirty yards, when they again make another stand, and again fly off. They repeat this movement several times, shortening their distance, and advancing nearer and nearer till they come within such a short distance that most persons think it prudent to leave them, not choosing to provoke them further.

Wild cattle.

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Mode of killing them.

The mode of killing them was perhaps the only modern remains of the grandeur of ancient hunting. On notice being given that a wild bull would be killed on a certain day, the inhabitants of the neighbourhood came mounted and armed with guns sometimes to the number of one hundred horse and four or five hundred foot, who stood upon walls or got into trees, while the horseman rode off the bull from the rest of the herd, until he stood at bay, when a marksman dismounted and fired. At some of these huntings thirty or forty muskets have been discharged before he was subdued. On such occasions the bleeding victims grew desperately furious from the smarting of his wounds and the shouts of savage joy that were echoing from every side. But from the number of accidents that happened, this dangerous mode has been little practised of late years; the park-keeper alone generally killing them with a rifled gun at one shot.

Habits of cows after calving.

When the cows calve they hide their young for a week or ten days in some sequestered situations, whither they go to suckle them two or three times a day. If the calves are approached by any person, they clap their heads close to the ground, and lie like a hare in form to conceal themselves. This is a decided proof of their native wildness; and if they are actually disturbed, they attack the assailant with the utmost fury, pawing and bellowing like an incensed bull. It is remarkable, too, that when any one of the herd happens to be wounded, or has grown weak and feeble through age or sickness, the rest set upon it and gore it to death.

Devonshire breed.

The *Devonshire* breed is said to be directly descended from this race, of which the best specimen is seen at Chillingham Park in Northumberland. The resemblance in in some points is very striking; but the animals are of a light red colour and rather small in size. The *Hereford* and *Sussex* cattle are nearly of the same colour, and in other respects possess similar properties, but are decidedly better milkers. The *Dutch*, or *short-horned* description, which are much esteemed in the Eastern Counties, yield a large quantity of rich milk and butter, fatten readily,

Hereford and Sussex.

Dutch.

Agriculture.

though they are on the whole of a delicate constitution.

Lancashire. The *Lancashire* breed is distinguished by long horns, thick hides, long close hair, coarse necks, and large hoofs; they are of various colours, but generally have a white streak along the back, and though they are not remarkably productive, they enjoy a hardy constitution.

Ditchley. The celebrated *Ditchley* breed is an improved variety of the Lancashire, being smaller and cleaner boned; they fatten well, but are not very highly valued by the dairyman as milkers.

Galloway. Besides the varieties now mentioned, there is the *polled* or *hornless* kind, the most esteemed of which are found in *Galloway*, a district in the South-West of Scotland. The true Galloway bullock is straight and broad on the back, and nearly level from the head to the rump; broad at the loins, not however with hooked bones or projecting knobs; so that when viewed from above the whole body appears beautifully rounded like the longitudinal section of a roller. He is long in the quarters, deep in the chest, short in the leg, and moderately fine in the bone. The prevailing colour is black or dark-brindled. Like the Devonshire ox, he is rather undersized; though when well fed he has been known to weigh about a hundred stone.

Cross of the Galloway. Dr. Coventry alleges that it is not more than seventy or eighty years since the Galloways were all horned, and very much the same in external appearance and character with the breed of black cattle which prevailed over the West of Scotland at that period, and which still abound in perfection, the large-sized ones in Argyleshire, and the smaller in the Isle of Skye. The Galloway cattle at the time alluded to were coupled with some hornless bulls, of a sort which do not now seem to be accurately known, but which were then brought from Cumberland; the effects of which crossing were thought to be the general loss of horns in the former, and the enlargement of their size; the continuance of a hornless sort being kept up by selecting only such for breeding, or perhaps by other means, or by the practice of eradicating with the knife the horns in their very young state.

Suffolk duns. The *Suffolk duns* are, according to Mr. Culley, nothing more than a variety of the breed now described, and differing only in colour.

Ayrshire. The *Ayrshire* cow is a valuable animal, as the milk it affords, although not very abundant, is uncommonly rich, and is given with very little interruption throughout the whole year.

Kyloes. The Highland *Kyloes*, as they are sometimes denominated, are in great request in the Southern Counties, on account of the delicate nature of their flesh.

Norlands. This is supposed to be a different breed from the *Norlands*, or such as are reared in the remote districts of Ross, Sutherland, and Caithness.

Orkney and Shetland. The Islands of *Orkney* and *Shetland* produce a very diminutive species of cattle, some of them not weighing more than two hundred pounds; but they feed well, and when brought to good condition in the meadows of the South, they bring in the market a remunerating price.

Welsh. Of *Welsh* cattle there seems to be two distinct kinds. The large sort are of a brown colour, with some white on the rump and shoulders, denoting a cross from the *long horns*, though in shape bearing no resemblance to them. They are long in the legs, stand high in proportion to their weight, are thin in the thigh, and rather narrow in the chine; their horns are white and turned upwards; they are light in flesh, and, next to the Devons, well-formed for the yoke, have very good hoofs, and walk lightly and nimbly. The other sort are much more valuable; colour black, with very little white; of a good useful form, short in the leg, with round, deep bodies; the hide is rather thin, with short hair; they have a lively look and a good eye; and the bones, though not very small, are neither large nor clumsy; and the cows are considered good milkers.

Choice for breeding. From a reference to the statements just made, it appears manifest that the improvement of the lower animals in form and value depends very much on the care of the breeder. In rearing live stock of all descriptions, it ought to be an invariable rule to select for parents such as are small-boned, straight-backed, smooth-skinned, and round-bodied, with clean necks, small heads, and little or no dewlap. Those, too, which are of a quiet and docile manner ought to be preferred, as they generally require less food, and are more easily fattened. Nor should the stock-farmer overlook the valuable quality of becoming early mature; a point in which the different breeds of cattle vary to a considerable extent. In the management of cows which are kept for breeding it is to be observed, that about a month or six weeks previously to the time of calving, they ought to be abundantly supplied with the richest kind of food; for it is found that by this treatment, a larger quantity of milk is obtained than when they are fully fed for a longer period.

Rearing. Mr. Marshall informs us that the method pursued for rearing calves in the Midland Counties is this: they are allowed to suck for a week or a fortnight according to their strength; they then have new milk in the pail for a few meals; next new milk and skim-milk mixed, a few meals more; then skim-milk alone, or porridge made with milk, water, and ground oats, and sometimes oil-cake until cheese-making commences; after which, whey-porridge, or sweet whey in the field; being careful to house them in the night until warm weather be confirmed. The treatment of young cattle from the time they are separated from their dams, or are able to subsist on the common food of the other stock, must depend upon the circumstances of the farm on which they are reared. In Summer their pasture is often coarse but abundant; and in Winter all good breeders give them an allowance of succulent matter together with straw or hay. Speaking of the short-horned variety, Mr. Culley remarks, that the first Winter they have hay and turnips; the following Summer coarse pasture; the second Winter straw in the fold-yard, and a few turnips once a day in an adjoining field, just sufficient to prevent the straw from binding them too much; the next Summer tolerably good pasture; and the third Winter as many turnips as they can eat, and in every respect treated as fatting cattle.

For the butcher. The farmer who feeds for the butcher-market has three separate methods to pursue; all of which will answer his purpose in certain circumstances, and his choice must be determined by the nature of his land, as well as by the main object which he had in view when he rented it. Live stock may be fattened on pasture ground, by *soiling* in proper yards or sheds, where they are supplied with abundance of green food; or lastly in the stall, where they are furnished with turnips, cabbages, and other succulent vegetables, combined with various descriptions of dry meat. The practice of pasturing cattle is the most natural and the most simple; and the owner can hardly go wrong, if he provide the animals with pure water and a sufficient shelter during the heats of Summer. Soiling is regarded by most

feeders as preferable to the other; even taken by itself, and more especially if connected with the general purposes of husbandry, the improvement of the fields, and the increase of corn produce. By this mode, too, the beasts are better protected both from insects and the weather; the food is consumed with less waste; and when the yards are suitably furnished with litter, a large supply of excellent manure is obtained. In this case, as in all others, due attention must be paid to the supply and quality of the water, as nothing contributes more to the health of young stock. The approach of Winter usually suggests the expediency of stall-feeding, as both warmth and cleanliness are essential to the accomplishment of this object. Besides, the cattle are kept more quiet and free from interruption, and are found in such circumstances to take in flesh more quickly. The food employed for this purpose consists of turnips, potatoes, carrots, cabbages, oil-cake, oats, barley-meal, beans, with different kinds of straw, cut small by means of machinery. The moist and dry food should be given in such proportions as to prevent any injurious effect on the digestive organs.

Desiderata. It has been remarked, that notwithstanding the high perfection to which certain breeds of cattle have been brought in Britain, and the great attention paid to every part of their management, several interesting points, which should be taken into calculation, remain still to be determined. Our knowledge, for example, is very incomplete in regard to the precise degree of nutriment afforded by different kinds of herbage and roots; the quantity of food consumed by the different breeds in proportion to the time of fattening and increase of weight; and the advantage of selecting the large or smaller varieties in any given circumstances of climate and produce. There is, no doubt, in every district a certain practical feeling which directs the stock-farmer in the choice of his cattle, and in the adaptation of means to the end, which he has in view; but, it is true, at the same time, that no successful attempt has been made to reduce such maxims to general principles, or to render the experience of one available to all.

Of Sheep.

Next to cattle, Sheep in many parts of the Country are esteemed a valuable stock, the whole income of the farmer being derived from their milk, wool, and flesh.

Different breeds. The numerous breeds of this animal are usually arranged into two classes: those which yield the *short* wool, and those which yield the *long*, or, as it is frequently described, the *combing* wool. To these, some writers have added the *mountain* breed; but so far as the wool is regarded as a characteristic, there is no room for this distinction. The first of these classes, however, including the one just stated, comprehends the varieties which are reared in the hilly districts of Wales, the North of England, and the Highlands of Scotland; the second embraces those which appear in Hereford, Dorset, Sussex, Norfolk, and some other places; and the last, or long-woolled, include the varieties which occupy the richer and more fertile vales of the Kingdom, and are known as natives of Leicestershire, Lincolnshire, and the banks of the Tees.

Mountain. The *mountain* sheep are distinguished by having black faces and legs, as well as large spiral horns. They are a very hardy race, and afford a delicate, well-flavoured mutton, though their wool is coarse and shaggy. The *Cheviot* breed, which likewise belongs to this class, has no horns; the face and legs are commonly white, and the eyes have a lively expression. The wool in this case is better than either the Welsh or Highland, and the animal is remarked as a good feeder, though the meat is not so highly valued in the market.

Cheviot.

Herefordshire. The second class, or *Herefordshire*, are comparatively small, have no horns, white legs and faces, and exhibit a fine short wool. They are also known by the name of *Rylands*. It has been observed of this description of stock, that they can subsist on less food than any other, and are remarkable for abstinence, and even for the endurance of hunger. The *South Downs* are also distinguished for the shortness and fineness of their wool, as well as by having grey faces and legs, small long necks, and affording a fine-grained, delicious mutton. This breed prevails in the dry, chalky grounds of Sussex. The *Norfolk* breed have a great resemblance to the Welsh or Scotch; having a black face, large spiral horns, short wool, and affording well-flavoured meat.

Rylands. South Downs. Norfolk.

Old Leicester. The long-woolled sheep are familiarly known by the names of *Lincolnshire*, or *Old Leicester*, and are distinguished by the want of horns, by their white faces, long, thin, and weak bodies, large bones, coarse mutton, and by having wool from ten to eighteen inches in length. This breed thrives only in the richest pastures, and is chiefly valuable on account of its wool. But it is from them that the *New Leicester*, or *Ditchley* breed is descended; a name derived from the place at which it was so much improved by the care and skill of the celebrated Mr. Bakewell. These animals attract attention by their lively eyes, fine heads, straight backs, barrel-shaped bodies, small bones, and a disposition to fatten at an early age. The weight of the quarter in ewes of three or four years old, is from eighteen to twenty-six pounds; in two years old wethers, from twenty to thirty pounds; and the length of wool varies from six to fourteen inches.

New Leicester. Ditchley.

The main excellence of this breed consists in their fattening more speedily, and on a smaller quantity of food, than any other; in their having a larger proportion of meat on an equal weight of bone; in the superiority of the meat itself both as to texture and flavour; in their valuable wool; in being ready for the market early in Spring; and in bringing, of consequence, a larger profit to the farmer.

Teeswater. The *Teeswater* variety have longer legs, finer bones, and a thicker and firmer carcass than the Lincolnshire; the mutton is better and finer grained, and the wool is shorter and less heavy. This is the largest breed in the Island, and is the most common in the rich meadows bordering on the river whence it derives its name. But, unfortunately, it seems to be calculated only for warm, well-sheltered pastures, and cannot therefore be transferred to the Cheviot range, or the still more exposed mountains of the Highlands, where its value would be duly appreciated. Besides, it requires to be fed abundantly in severe Winters; an attention which could not be conferred upon it in a hilly country, or in the extensive sheep-walks of Wales or Argyle.

Romney-marsh. There is also a variety, which bears among breeders the designation of the *Romney-marsh*, and which possesses many good properties. It has no horns; the face and legs are white; the body rather long, but well-shaped, and the bones somewhat large. The wool, however, is excellent, having a considerable length, and a beautiful colour. Like the Teeswater breed, it requires rich pasture, and a greater degree of care

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Hardwick. The *Hardwick* sheep are peculiar to that rocky district whence flow the Duddon and the Esk, in the County of Cumberland. They are without horns, have speckled faces and legs, short wool, which, though not by any means fine, is greatly superior to that produced by the heath or mountain sheep, properly so called.

Dun-faced. The *Dun-faced* breed seems to have been imported into Scotland from Norway or Denmark at a very early period, and is still found in most of the Counties beyond the river Forth, though not in large numbers. Of this ancient race there are now several varieties produced, as usual, by peculiarities of situation and different modes of management. In *Shetland*, it would appear, there are two varieties of the sheep, one of which is considered aboriginal, and bears very fine wool; but the number of these is much diminished, and in some places they have been entirely supplanted by foreigners. The other variety carries coarse wool above, and fine, soft wool below. They are said, moreover, to have three different successions of wool yearly, two of which have a greater resemblance to long hair, and are termed by the common people *fors* and *scudda*. When the wool begins to loosen in the roots, which generally happens about the month of February, the hairs or *scudda* spring up; and when the wool is carefully plucked off, the tough hairs continue fast until the new wool grows up about a quarter of an inch in length, when they gradually wear off; and when the new fleece has acquired about two months' growth, the rough hairs, termed *fors*, spring up and keep root until the proper season for pulling them arrives, when they are plucked off together with the wool, and separated from it at dressing the fleece by an operation called *forsing*. The *scudda* remains upon the skin of the animal, as if it were a thick coat; a fence against the inclemency of the seasons which provident Nature has furnished for supplying the want of the fleece in a high and stormy latitude. The wool is of various colours; the silver grey is thought to be the finest; but the black, the white, and the brown are very little inferior; though the pure white is certainly the most valuable for all the finer purposes in which combing wool can be used.

Shetland.

Merino. Our catalogue would be incomplete did we not mention the *Merino*, which, though not a native of Britain, has already acquired considerable importance. This sheep was brought into England in 1788, but did not excite much interest till the year 1804, when George III. began his sales. The patriotic object contemplated by His Majesty of spreading them widely over the Country and subjecting them to the experiments of the most eminent professional breeders, has been in a great measure accomplished by the institution of the *Merino Society*, which includes among its Members some of the greatest landholders in the Kingdom. For some years past, however, this breed, notwithstanding all the care bestowed upon it, is acknowledged to have been on the decline; and we may add, that it has succeeded best in those cases where it was judiciously crossed with a native variety, without any attempt to preserve it pure.

Merino fleeces. Every one knows that the Merino is chiefly valued for its uncommonly fine fleece, which upon the average weighs from three to five pounds. In colour it is unlike that of any English breed. There is in the surface of the best Spanish fleeces, a dark-brown tinge approaching to black, which is occasioned by dust adhering to the greasy properties of its pile; and the contrast between this tinge and the rich white colour below, as well as that rosy hue of the skin which denotes high proof, excites, at first sight, no little surprise. The harder the fleece is, or, in other words, the greater resistance it makes to the pressure of the hand, the finer is the wool esteemed; here and there, indeed, a fine pile may be found in an open fleece, though this occurs but rarely. Nothing, however, tends to render it more unsightly to the English eye than the large tuft of wool which covers the head: it is of very inferior quality, and is ranked with what is produced on the hind legs; on which account it does not sort with any of the three classes; *viz.* the *rafinos*, or prime; *finos*, or second best; and the *terceros*, or third, and of course is never exported from Spain.

Carcasses. Among the Merinos, the male has horns, the female none, or very rarely; the faces and legs are white, and the bones fine. The average weight per quarter of a tolerably fat ram is about seventeen pounds, and that of a ewe about eleven pounds. The shape, if we take the ideas of English breeders for a standard, is far from perfect. The pendulous skin beneath the throat, which is usually accompanied with a sinking or hollowness in the neck, is accounted a deformity here, though in Spain it is much esteemed, as denoting both fine wool and a heavy fleece. Yet the Spanish sheep, generally speaking, are level on the back and behind the shoulders; and Lord Somerville has proved that there is no reason whatever for connecting the peculiarity of form just mentioned with the amount or quality of wool.

Works on breeding. We cannot enter upon the extensive subject of breeding, considered in a professional point of view; holding it enough to refer such readers as are desirous of full and accurate information to the Treatises of Dr. Parry, Sebright, Culley, Sir John Sinclair, Mr. Johnston, the *General Report of Scotland*, the Work of Mr. Bakewell; Marshall's *Rural Economy*; the *Farmer's Calendar*; *Communications to the Board of Agriculture*; the *Middlesex Report*; and to a variety of able Essays in the *Quarterly Journal of Agriculture*. We shall, notwithstanding, quote from the last of these publications a notice relative to a "method of obtaining a greater number of one sex at the option of the proprietor, in the breeding of live stock." The Essay, at length, is to be found in the *Annales de l'Agriculture Française*, and is worthy of attention, as containing the details of some interesting experiments made with the view just stated. M. Girou proposed, at a meeting of the *Agricultural Society of Séverac*, on the 3d of July, 1826, to divide a flock of sheep into two equal parts, so that a greater number of males or females, at the choice of the proprietor, should be produced from each of them. Two of the Members of the Society offered their flocks to become the subject of his experiments, and the results communicated were, to some extent, in accordance with the author's expectations.

Experiments on the different sexes.

The first experiment was conducted in the following manner. He recommended very young rams to be put to the flock of ewes from which the proprietor wished the greater number of females in their offspring; and also that during the season when the rams were with the ewes they should have more abundant pasture than the other; while to the flock from which the owner wished to obtain male lambs chiefly, he recommended to put strong and vigorous rams, four or five years old. The following Tabular view contains the result of this experiment.

Flock for Female Lambs.		
Age of the Mothers.	Sex of the Lambs.	
	Males.	Females.
Two years	14	26
Three years	16	29
Four years.........	5	21
Total. .	35	76
Five years and older	18	8
Total. .	53	84

N. B. There were three twin births in this flock. Two rams served it, the one fifteen months, the other nearly two years old.

Flock for Male Lambs.		
Age of the Mothers.	Sex of the Lambs.	
	Males.	Females.
Two years	7	3
Three years........	15	14
Four years.........	33	14
Total. .	55	31
Five years and older	25	24
Total. .	80	55

N. B. There were no twin births in this flock. Two strong rams, one four, the other five years old, served it.

The second experiment is thus related by the author. "During the Summer of 1826, M. Cournejouls kept upon a very dry pasture, belonging to the village of Bez, a flock of 106 ewes, of which 84 belonged to himself, and 22 to his shepherds. Towards the end of October, he divided his flock into two sections of 42 heads each, the one composed of the strongest ewes, from four to five years old; the other of the weakest beasts, under four or five years old. The first was destined to produce a greater number of females than the second. After it was marked with pitch in my presence, it was taken to much better pasture behind Panouse, where it was delivered to four male lambs, about six months old, and of good promise. The second remained upon the pasture of Bez, and was served by two strong rams, more than three years old. The ewes belonging to the shepherds, which I shall consider as forming a third section, and which are, in general, stronger and better fed than those of the master, were mixed with those of the second flock. The result was that the

	Males.	Females.
First section gave	15	26
The second	26	14
The third	10	12
In the first section there were two twin births	0	4
In the second and third there were also two..................	3	1

Apparent general law. Besides these very decisive experiments, M. Girou relates some others made with horses and cattle, in which also his success in producing a greater number of the one sex than of the other appears. The general law, so far as we are able to detect it, seems to be, that when animals are in good condition, plentifully supplied with food, and kept from breeding as fast as they might do, they are most likely to produce females. Or, in other words, when a race of animals is in circumstances favourable to its increase, Nature produces the greatest number of that sex which, in animals that do not pair, is most efficient for increasing their numbers. But if they are in a bad climate, or on stinted pasture, or if they have already given birth to a numerous offspring, then Nature produces more males than females. Yet perhaps it may be premature to deduce any general law from experiments which have not yet been sufficiently extended.

Swine. Among the live stock produced on farms we must not omit *Swine*, of which there are numerous varieties reared in Great Britain. The *Berkshire* breed is of a reddish colour, with short legs, large ears, and a thick, compact, well-formed body; is readily disposed to fatten, and grows to a large size; but the supply of food must be constant and abundant. The *Chinese* or *black* breed is of small size, short legs, and of a good make; is considered one of the most profitable in the country; the flesh is delicate, and it fattens freely even on indifferent food. The *Gloucestershire* variety is white, and of a large size, the form not symmetrical, and in other respects not highly esteemed among feeders. The *Hampshire* breed is also white, attains a large bulk, and fattens readily. The *Northamptonshire* is remarkable for the enormous length of its ears, is of great size, but does not fatten easily. The *Rudgewick* breed takes its name from a village situated on the confines of Surrey and Sussex; it is a valuable variety because it not only grows well, but also fattens at small expense. The *Woburn* breed was introduced by the late Duke of Bedford; it is usually spotted, though the colour is various; the size is large, and it fattens so well that it attains nearly twice the weight of other hogs in the same space of time. The *Highland* or *Irish* variety is described as an inferior, animal being small and ill-shaped, and, at the same time, difficult to fatten, or otherwise to improve in its marketable value.

Berkshire. Chinese. Gloucestershire. Hampshire. Northamptonshire. Rudgewick. Woburn. Highland or Irish.

It is worthy of notice that Mr. Culley mentions only three breeds of Swine, the Berkshire, the Chinese, and the Highland or Irish; while other writers have found a distinct breed in almost every County of England. In addition to those already described, there is the *Sussex* pig, which is distinguished by being black and white, but not spotted; it grows to the weight of eighteen or twenty stone. To these we may add the *Cheshire*, the *Suffolk*, and the *Shropshire*. In Scotland little progress has hitherto been made in the improvement of this stock, if we except the Counties of Dumfries and Galloway. The prevailing breed is of a white colour; they have light carcasses with bristles standing up from nose to tail, long legs, and are very slow feeders at any age. In the *Hebrides*, the breed, supposed by Dr. Walker to be the aboriginal, is of the smallest size, neither white nor yellow, but of a uniformly grey colour, and shaggy, with long hair and bristles. They graze on the hills like sheep; their sole food is herbage and roots, on which they live the whole year round, without shelter, and without receiving any other sustenance. In Autumn,

Sussex. Cheshire. Suffolk. Shropshire. Scotch. Hebridean.

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when they are in the best order, their meat is excellent, and obtained without any artificial feeding; but when driven to the low country they fatten readily, and grow to a considerable size.

Profits of Swine.

Notwithstanding the extent to which Swine are reared, it still remains a disputed point among Agriculturists whether the breeding and fattening of that species of stock, beyond the mere offal of the farm, has ever been rendered a remunerating branch of rural economy. On every establishment there is a great deal of stuff, roots, herbage, and waste corn, which would otherwise be lost; and hence it is manifest that, so far as the use of these articles is concerned, the pig must be a profitable animal. But it is, nevertheless, very doubtful whether, on fertile lands, any portion of the crop could be so applied as to place the breeding of Swine on the same footing, as to revenue and other advantages, as that of cattle and sheep. It has been calculated that, with proper management, on a farm of three hundred acres, of which two hundred are kept in tillage, an annual profit to the amount of £100 might be secured by rearing pigs; though it is admitted by the same author that, as soon as this stock exceeds the quantity of superfluous produce on which it is usually maintained, it ceases to be in any respect beneficial. The reader will find many useful observations on this branch of the subject in Culley's Work already mentioned; the *Complete Grazier*; Henderson *on Swine*; the *Farmer's Magazine*; and the *General Report of Scotland*.

On the Dairy.

We remarked at the commencement of this division that live-stock are raised not only for their flesh and labour, but also for their milk. In some parts of the country a large proportion of land is devoted to this object, and the rents of the farmer, as well as the affluence of the proprietor, are derived from the manufacture of milk in its various forms of butter and cheese.

House,

It is recommended by practical persons that the building meant for the several processes of the dairy should be erected in a cool situation, and protected from the direct approach of the solar rays, and even of a current of air varying much in temperature. The utmost cleanliness, too, is altogether indispensable. The house should be paved with stone or brick, having a gentle inclination so as to be readily dried, and the floor should be washed every day during Summer. To preserve the air cool, or at least of an equal temperature, it has been thought advisable to admit a small stream of water into the apartments, or even to be poured like a cascade from the ceiling.

and utensils.

The utensils, which are commonly of wood, ought to be cleansed with the greatest care; or if metallic, or glazed earthen vessels be substituted, they should be daily plunged into hot water, scoured with salt, and well dried before they are filled with milk. Cast-iron dishes, enamelled or fluted with tin, have been lately introduced into some dairies, and are found to answer well, both on account of their cleanliness and durability.

Care in milking.

It is known to every one that the quality of milk is much affected by the nature of the food on which the animal is fed; but it is not so generally understood that the quantity depends a good deal on the mode of milking. If any difficulty occur in conducting this operation the cow should never be treated harshly, as it more frequently proceeds from pain than from obstinacy of temper. The hardness of the udder will in general denote whether there be any obstruction; in which case fomentations, together with gentle friction, ought to be used, until the flow of milk be restored. In Summer, cows ought to be milked at three equal intervals in the course of twenty-four hours; by which means the quantity is increased without deteriorating its essential properties of richness and flavour. The depth of the vessels into which the milk is poured, should not exceed three inches; and should any peculiarity of taste be occasioned by the nature of the food, it may be removed by boiling two ounces of nitre in a quart of water, and plunging about a teacup-full of the mixture into a pail of the warm milk. Those who are particular in the manufacture of butter and cheese, keep the milk of every cow separately, so as to discriminate their respective qualities, and avoid all improper combinations. With the same view care is taken that the cattle shall not be hastily driven from the field to the dairy, and that the milk shall not be much agitated or shaken in the pails after it is drawn; for in either case the liquid acquires a tendency to acidity which soon renders itself perceptible in the finer kinds of butter.

Churning.

Of late years the resources of mechanical invention have been applied to lighten the labour and facilitate the object of churning. It has been found, however, that the chief secret in the management of this process, whatever be the form of the apparatus employed, is to continue the agitation with the same regular, uniform, uninterrupted motion from the beginning to the end; because it is suspected that a too rapid or unequal motion communicates to the butter a bad flavour in Summer, while, in Winter, it endangers the success of the operation altogether. A table-spoon-ful of distilled vinegar, added to the cream after it has been a considerable time moved, has occasionally proved beneficial in separating the butter, after other means had appeared to fail.

Experiments on temperature.

A few years ago some interesting experiments were made by Dr. Barclay, a well-known Physiologist, and another professional gentleman at Edinburgh, with the view of ascertaining the temperature at which butter can be best procured from cream. The results were communicated to the *Journal of Agriculture*, from which we abridge the following particulars. In the first experiment fifteen gallons of cream were put into the churn at the temperature of 50° Fahrenheit; the weight per gallon having been previously ascertained to be eight pounds four ounces. By agitating the cream in the usual manner for the space of two hours the temperature rose to 56°; at the end of the churning, being four hours from the commencement of the operation, the temperature was found to be 60°, or 10° higher than at the beginning. The quantity of butter obtained in this process was twenty-nine pounds and a half avoirdupois, or nearly two pounds of butter for every gallon of cream put into the churn. The butter appeared to be of the very best quality, being firm, and rich and pleasant to the taste. A gallon of the churned milk being carefully weighed, gave eight pounds nine ounces, being an increase in weight of eight ounces per gallon above that of the cream used in this experiment.

In the second experiment, fifteen gallons of cream were put into the churn at the temperature of 55°, the weight per gallon being eight pounds two ounces. By agitating the cream as formerly, for one hour and a half, the temperature rose to 60°: at the end of the churning, being three hours and fifteen minutes from the begin-

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A third experiment was performed, in which the same quantity of cream was put into the churn, at the temperature of 58°, the weight per gallon being eight pounds two ounces. At the end of one hour's churning the temperature had risen to 63°; and at the end of the process, which lasted three hours, the temperature was found to be 67°. The quantity of butter obtained by this experiment was twenty-eight pounds, and in quality it seemed to be rather inferior to that produced in the two former, being rather soft and spongy.

The fourth experiment was performed on the same quantity of cream, the temperature being 60°, and the weight per gallon eight pounds one ounce. During the process of churning the temperature increased as formerly; and at the end of three hours, when the operation was finished, it was ascertained to have risen to 68°. The quantity of butter was twenty-seven pounds, of a quality much the same as that produced in the third experiment, but decidedly inferior to that of the first and second. A gallon of the churned milk weighed eight pounds eight ounces.

In the fifth experiment, fifteen gallons of cream were used as before, at the temperature of 66°, and the weight per gallon eight pounds. The churning occupied two hours and a half; at the end of which space the temperature was found to have risen to 75°, being an increase of 9°. The quantity of butter was twenty-five pounds eight ounces, of a quality sensibly inferior to that produced in any of the former experiments; being of a less promising appearance, a soft and spongy consistence, and not so pleasant to the taste. The weight of a gallon of the churned milk was eight pounds seven ounces.

Results. From these experiments it appears that cream should not be kept at a high temperature in the process of churning. In the first experiment, where the temperature was lowest, the quantity of butter obtained was in the greatest proportion to the quantity of cream used; and as the temperature was raised, the proportional quantity of butter diminished; while in the last experiment, where the mean temperature of the cream had been raised to 70°, not only was the quantity of butter diminished, but in quality it was found to be very inferior, both with regard to taste and appearance. That the lowest possible temperature should be sought in churning, appears likewise from another result of the above experiments; namely, that the specific gravity of the churned milk was found to diminish as the temperature of the cream had increased; thus showing that at the lower temperatures, the butter which is composed of the lighter parts of the cream, is more completely collected than at the higher temperatures, in which the churned milk is of greater specific gravity. In general, it was inferred, that the most proper temperature at which to commence the operation of churning is from 50° to 55°; and that at no stage of the operation ought it to exceed 65°: while, on the contrary, if at any time the cream should be under 50° in temperature, the labour will be much increased without any proportionate advantage being obtained; and a temperature of a higher rate than 65° will be injurious as well to the quality as to the quantity of the butter.

Butter for keeping. Butter is usually preserved for future purposes by means of common salt. The following preparation is an excellent substitute, and imparts a richer and sweeter taste. Two parts of good sea salt, one part of loaf sugar, and one of saltpetre, are pounded and mixed together. One ounce of this mixture is incorporated with every pound of butter, which is then closed up in a proper vessel, and at the end of two or three weeks it is fit for the table. When thus prepared, it has been known to retain its sweetness several years.

Dutch butter making. In Holland the method of making butter is to allow the milk, after it is drawn from the cow, to become completely cool before it is put into the pans or cream dishes; to prevent the cream from separating from the milk by stirring it two or three times a day with a wooden spoon, and when it is sufficiently thick to churn it for an hour. When the butter begins to form, a quantity of cold water is poured in for the purpose of separating the butter from the milk: and when the former is taken out, it is washed and kneaded till the last water comes off pure. It is said that milk managed in this way yields a larger proportion of butter than by the ordinary method practised in this Country; and that it is, at the same time, of a better quality, sweeter, firmer, and well calculated for keeping.

Cheese. *Cheese* is also a very important article of Dairy manufacture; of the History and Antiquities of which we have spoken in our *Miscellaneous Division*. Much, no doubt, depends on the quality of the pasture, as well as on the season of the year at which the process is conducted; but it is proved by recent experiments that a great deal is left to the skill of the farmer, and that the raw material is capable of being converted to much higher uses than the ignorant have heretofore imagined. The very first step, the coagulation of the milk, is attended with considerable consequences, as giving a decided taste and character to cheese. It is well known that the rennet which is employed for this purpose is prepared from the stomachs of young calves, and, unless great precautions are used, it is apt to become rancid, and thereby to communicate a disagreeable flavour. The method of preserving it, in the West of England, is, when the rennet-bag is cleaned, to make a strong solution of salt with two quarts of water; to add to this solution small quantities of several spices, and to boil the whole down to three pints; then, to strain the liquor and pour it on the rennet-bag; to add a sliced lemon; and, after allowing it to settle a day or two, to strain it well, and bottle it up for use. When well-corked, it will keep a year, and gives to the cheese a pleasant aromatic flavour. A decoction of the flowers of the *Galium verum*, or cheese-rennet, a plant very common in many pastures, is sometimes used as a substitute. Muriatic acid is also employed for the same purpose; and we are told, that the pungent taste peculiar to some sorts of Dutch cheese, is occasioned by the latter ingredient, infused, perhaps, in an undue proportion.

Rennet.

Colouring matter, arnotto. The colouring matter most commonly adopted in English dairies is *arnotto*, an article which was wont to be imported from Spain; the quantity varying according to the shade required. In Gloucestershire, an ounce is allowed for every hundred pounds of cheese. In Cheshire, the method of using it is to tie up the necessary quantity in a linen bag, and to infuse it in half a pint of hot water the night before it is used, and next morning, before the application of the rennet, to mix the coloured infusion thoroughly with the milk. In some places, a piece of the unpounded *arnotto*, dipped in milk, is rubbed on a smooth stone, and the colouring matter

thus obtained, is combined with the milk in the usual way.

Gloucester cheese. In making *Gloucester* cheese the milk is used as it is drawn from the cow; and if it be too hot in Summer a little skim-milk or water is added. After the application of the colouring-matter and the rennet, the curd is carefully broken down with the hand or a knife; and next put into a vat, and pressed for a quarter of an hour. It is then turned into a tub and again broken small, scalded with a pailful of water, lowered with one part of whey, and the whole is briskly stirred. Having stood a few minutes to allow the curd to settle, the liquor is strained off, and the curd is again collected into a vat. When this is half full, a little salt is sprinkled on and well wrought into the cheese; it is then filled up: the whole mass is turned two or three times round; the edges are pared and the middle rounded at each turning. The cheese, surrounded with a cloth, is subjected to further pressure, when the process is completed.

Imitated. In the 1st volume of the *Quarterly Journal of Agriculture*, there is "a Receipt for making cheese, in imitation of double Gloucester." The method adopted does not differ much from that now described, and the success of the attempt, which was made in Dumfrieshire, shows that the secret, if there ever was any, is now perfectly understood from Cornwall to the Scotland Firth. The quantity of *arnotto* used by the imitator amounted to about a quarter of a pound for two hundred weight of cheese; and the salt to about eight or nine ounces. It was found that a hundred quarts of milk were required for a cheese of thirty pounds; or about three quarts to the pound.

Stilton. The directions for making *Stilton* cheese are given in the *Agricultural Report of Leicestershire* as follows: the night's cream is put into the morning's new milk, with rennet; and when the curd is formed, it is not broken, as is done with other cheeses, but taken out whole and placed in a sieve, to drain gradually, and as it drains, a gradual pressure is continued till it becomes firm and dry. It is then placed in a wooden hoop, and afterwards kept dry on boards, and turned frequently with the cloth binders round it, which are tightened as occasion requires. When the cloths are removed, each cheese is rubbed with a brush once every day, and in damp weather twice, for two or three months. This cheese has been successfully imitated in other districts, an account of which will be found in the *Quarterly Journal*, No. VI. and in the *Prize Essays and Transactions of the Highland Society*.

Cheshire. *Cheshire* cheese, which it is found more difficult to imitate than any other, is made in the following manner. The cream of the preceding evening's milk is skimmed off, and poured into a pan heated with boiling water, and a third part of the same milk is heated in the same way. The new milk of the morning and that of the preceding evening being thus prepared, are introduced into a large tub together with the cream. Then are added, first the colouring matter, and afterwards the rennet. The whey being removed, the curd is cut into slices, and repeatedly turned over and pressed with weights. It is next broken with the hand into small pieces, put into a vat, and strongly pressed, and being transferred afterwards into another vat, the process of breaking down and pressing is renewed two or three times. The last time, the vat is heated to a certain temperature, and a tin hoop or binder is put round the edge of the cheese. Six hours are spent in the processes now detailed, and eight hours more are necessary for pressing the cheese, during which time it should be twice turned in the vat. Next morning and evening, it is again turned and pressed, as well as in the morning of the third day, about the middle of which it is removed to the salting apartment, when the outside is well rubbed with salt, and a cloth binder is passed round it. During a week, while the cheese remains there, it is turned twice a day, and as it is left for some days longer to dry, it is turned once and well cleaned daily. It is then transferred to the store-room, which should be kept moderately warm, and protected from a current of air, to avoid the risk of cracking, and turned every day till it becomes perfectly dry.

Parmesan. No cheese is more highly esteemed than *Parmesan*, which is produced on the plains of the Po, near Lodi. Its peculiar qualities, we are informed, depend more on the manner of making it than any thing else. The cows are a mixed breed, between the red Hungarian, or Swiss variety, and those reared among the Lombards. The chief peculiarity in their feeding is, that they are allowed to eat in the fields four or five hours out of the twenty-four; all the rest of the time they are stalled, and get hay. Both this pasture and hay are chiefly from irrigated lands. The cheeses are made entirely from skimmed milk; half of that which has stood sixteen or seventeen hours, and half of that which has stood only six. The milk is heated and coagulated in a cauldron, erected in a very ingenious fire-place, being an inverted semicone in brick-work, well adapted for preserving heat, and for the use of wood as fuel. Without being taken out of the cauldron, the curd is broken very small by an instrument consisting of a stick with cross-wires; it is again heated, or rather scalded, till the curd has attained a considerable degree of firmness; it is then taken out, drained, salted, and pressed, and in forty days it is fit to be put in the cheese loft. The peculiarities of this cheese seem to depend on the mode of scalding the curd; though some allege that the feeding of the cows is not without its effect. But for a more minute detail, we refer the reader to the XXIst Volume of the *Farmer's Magazine*; Cadell's *Journey in Carniola*; and Loudon's *Agriculture*.

Other cheeses. There are various other cheeses in common use, such as the *Chedder*, the *Dunlop*, the *Lincolnshire*, the *Norfolk*, the *Wiltshire*, the *Cottenham*, and the *Suffolk*; but as the process of making is nearly the same in all, we shall not repeat descriptions which would exhaust the patience without conveying any particular knowledge. We shall simply remark that cheeses ought to be kept in a dry airy place; and that the leaves of Tutsan, the *Hypericum androsæmum*, or of the Yellow Star of Bethlehem, or even the young twigs of the common Birch, are useful in preventing the depredations of mites.

Leases and Rent.

General principles. Few subjects in Agriculture are attended with greater difficulty than the proper mode of fixing the duration of Leases and the amount of Rent. With regard to the former, it may be observed, that when they are short and clogged with a number of restrictive clauses, they are equally injurious to the proprietor and to the occupier of the land, and have therefore been justly regarded as one of the most serious obstacles to the improvement of

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the soil. As to rent again, no general principle can be stated which is not liable to certain objections. Some writers have suggested that one-third of the produce should be appropriated to the landlord. But as land of inferior quality requires a more expensive mode of cultivation than richer fields,—more skill, capital, and industry, to improve and keep it in a productive state,—the fourth part of the produce might be considered as the fair value of rent. Nay, from the recent examination of some very intelligent Agriculturists before a Committee of the House of Commons, even the fifth part of the actual produce of poor land was deemed an equitable return to the landlord. In all leases, therefore, founded on such principles, the quality of the soil must determine the proportion to which the proprietor is entitled in name of rent. Perhaps the main considerations connected with this subject might be examined under the following heads; namely,

Inquiries.

I. Whether it is more for the interests of Agriculture that the lands of a country should be let on lease, than that they should be occupied by tenants at will?

II. What is the proper length of a lease, and what are the reasons of preferring one period to another?

III. Whether ought the rent to be a constant money-payment, or a *fixed quantity* of produce, or a fixed *proportion* of the produce of the land?

IV. Whether ought there to be any stipulations in a lease with respect to the management of the farm; and to what points ought they to be directed?

V. Whether ought a farm to be let privately or publicly. And whether ought the highest bidder, supposing him to be in other respects unobjectionable, always to be preferred?

VI. Whether ought houses and buildings to be erected by the landlord or tenant?

ses pre- able to ncy at

I. As to the first question, whether it is more for the interests of Agriculture that land should be let on lease, or be occupied by tenants at will, it may, we presume, be determined by an appeal to the fact, which of the two has been found to call into action the greatest share of capital, industry, and skill. If guided by this principle, we shall have no difficulty in deciding in favour of leases, in preference to the system of renting land from year to year. By the former method, say on a lease of nineteen years, the tenant is perfectly certain of reaping the benefit of the capital expended in improving the land; and consequently, may be expected to apply his skill to the improvement of his farm without hesitation. He can also, with perfect security to himself, adopt the most improved rotation of cropping, which, let it be observed, is generally to make a present sacrifice for a future advantage; whereas, if he is a tenant at will, in the strict sense of that phrase, he cannot be expected to do either the one or the other. Nothing would be more absurd, than for a tenant whose term of removal may be only twelve months hence, either to lay out capital, or to adopt a system of culture, the return from which could be expected only at a distant period. We are aware that many tenants at will, from the practice on the estate, or the character of the proprietor, feel a degree of security nearly approaching to that which is conferred by a lease. Though this, however, be the case in some particular instances, it cannot apply to landlords in general. A tenant, therefore, so circumstanced, cannot fail to apprehend, that were he to make any great improvement on his farm, a higher rent might be exacted.

Advantages derived from Leases.

There is one objection which we have heard stated to letting land on a lease of nineteen years, namely, that if the farm happens to be too low rented, the tenant continues during the lease, and enjoys a portion of the produce which should have fallen to the share of the landlord; but, on the other hand, should the stipulated rent prove too high, the landlord must submit to a deduction. This objection is plausible; and may, on a superficial view of the case, appear conclusive against the system of letting lands upon lease. Those who take this view, however, very probably forget, that the security of a lease for a fixed and definite period, has been one of the principal causes of the rapid progress of Agriculture during the last fifty years. If the same impulse could have been given to Agriculture in the hands of tenants at will, the view entertained by such persons would, no doubt, be correct. But this is supposing a state of things which cannot possibly exist. For it proceeds upon the idea, that Man will display the same energy, and make as great exertions for the acquisition of an object which another may enjoy, as he will for that which he knows will be exclusively his own. Indeed, there seems great reason for thinking, that had the practice of letting lands to tenants at will been universal, the rental of the Country would not have exceeded two-thirds of what it is at present; and, therefore, although a landlord may occasionally be obliged to accept of a rent somewhat lower than his lands are worth, still he is a great gainer on the whole. It may be supposed, that we have overrated the effect of leases, but, when it is taken into account, that previously to their introduction almost every improvement was effected by the proprietor, and that in all districts in which they are generally adopted, the tenants have relieved the landlords of this burden, the benefit resulting from this method will not be questioned. Of course we are here speaking of such improvements as add to the productiveness of the soil, and at the same time yield a profit on the capital expended. In short, it may be held, that no tenant at will, possessing an ordinary portion of common sense and prudence, can be expected to lay out capital, which will not be returned within a very short period; and this, it is obvious, amounts to laying out no capital at all on that description of improvements which make the largest return.

Disadvantages of tenancy at will.

By the conditions of letting, he might be bound to a certain mode of cropping, which would in some measure tend to prevent the deterioration of the lands; but every operation would be performed in a slovenly manner, and with a view as far as possible to save expense. If, on the other hand, from the character of the landlord, or practice on the estate, the tenants were perfectly secure of not being removed from their farms, it is equally obvious in this case, that the cultivation of the lands would not be carried to the highest pitch; because most tenants would feel, that were they to improve their farms highly, a larger rent might be exacted. And this might occur even with liberally disposed landlords, as an experienced eye and very considerable skill are requisite, to discriminate betwixt that productiveness which is the result of natural fertility, and that arising from high improvement and skilful management. This is a risk, to which all tenants at will must know they are exposed; and in the majority of cases, they will avoid making improvements of which they are not certain of reaping the benefit.

II. With these few remarks, we shall proceed to

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notice the *second* point; namely,—"What is the proper length of a lease,—or what are the reasons for preferring one period to another?"

Advantages of Leases nineteen and one and years.

The circumstances of farms, as to situation, soil, and improvement, are so various, that it is impossible to fix on any length of lease which ought to be preferred in every instance. Where the land is rich, and in a highly improved state, a shorter period may suffice, than in those cases in which extensive improvements must be executed by the tenant, and the means of effecting them are at a distance. On the whole, however, when we consider the immense benefits which Agriculture has derived from leases of nineteen or twenty-one years, we are disposed to think, that it would not be easy to fix on any period more advantageous for the greater part of lands which have been under cultivation. This period seems well adapted for inducing the tenant to execute promptly those improvements which are generally the most profitable, while, at the same time, it affords ample space for his reaping a full and fair return for the necessary outlay. When the period of the lease is much further extended, many tenants are apt to feel, that there is time enough to reap the benefit of an improvement, even though its execution be delayed for a few years; and consequently, their exertions at the commencement of the lease are less prompt and vigorous; the effect of which, in many instances, is to give rise to a dilatory and listless mode of proceeding, which often leads to the neglect or total abandonment of many improvements contemplated at the commencement of the lease. On the other hand, if the lease be for a period much shorter than nineteen years, the tenant, except in situations very favourably situated for manure and other means of improvement, does not feel that he has sufficient time for putting his lands in a very high state of cultivation, with a reasonable prospect of being remunerated. For it must be kept in view, that profit from superior culture is not derivable to any considerable extent, from merely bringing the lands to a high degree of fertility, and in a few years, by severe and injudicious cropping, reducing them again to their former state. Profit can only be derived to the fullest extent, by *keeping up* and *directing* the capabilities of the soil, whether natural or acquired, to the production of those crops which will prove immediately profitable to a certain extent, and still more by the influence which they exercise on the succeeding ones. This cannot take place, except in a very few cases, if the lease be much shorter than nineteen years.

Renewals.

On the whole, we have no hesitation in giving the preference to nineteen or twenty-one years, as the period most advantageous to the interests of the landlord, the tenant, and the community at large; though, as we have stated before, there may be cases where a shorter period would not be attended with any very striking disadvantages; and there are others where a considerable extension might prove highly beneficial. It would, in our opinion, be a great improvement, if the lease could be renewed at the end of the fifteenth or sixteenth year; as the tenant's exertions are necessarily lessened during the last four or five years of the lease. We would strongly recommend to landlords, when they have a proper tenant, to effect this arrangement with him. The oftener this can be done without giving the latter reason to expect it at the commencement of his lease, the better for all parties.

III. The *third* question to be considered is,—"Whether the rent ought to be a constant money-payment, or a fixed quantity of produce, or a fixed *proportion* of the produce of the farm?"

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Object of rent.

This the reader is aware, involves a point of considerable difficulty; and one which has been of late the subject of much controversy and discussion. The object which most writers on the subject have had in view, is the discovery of a principle of paying rent, by which the tenant shall give the precise worth of the farm *each* year of the lease. This appears to us a state of things which never can be attained.

Disadvantages of the metayer system.

We shall, in the first place, offer a few remarks on the comparative merits of a fixed money-rent, and *a fixed proportion* of the yearly produce: and, on this head we may observe, that the fluctuations which have occurred of late years in the *money-price* of farm produce, from the changes in the value of the currency, and the occurrence of harvests more or less productive, would be apt on the first statement of the question to decide us in favour of a fixed *proportion* of the produce of the farm, or the *metayer* scheme. Of this system, however, we are disposed to think very unfavourably, because its whole tendency is to check enterprise and improvement. Its practical operation is well illustrated by the state of Agriculture in those Countries where it prevails; for which see, among others, an excellent account in Chateauvieux, *Lettres Ecrites d'Italie en 1812 et 1813*, and the *Annales Agricoles de Roville*, published about four years ago at Paris. No tenant would expend capital when he knew that the landlord was to come in for a third, fourth, or fifth share of the additional produce resulting from its application. It is a system applicable only to Countries where the tenantry have little or no funds, and must look to the landlords for stocking their farms. Indeed, so pernicious does it appear to us, that we see no chance of the Agriculture of a Country becoming really prosperous where that system of letting lands is universal.

Doubts respecting a fixed money-rent.

From a fixed money-rent, no great inconvenience seems to have been felt in this Country, previously to the passing of the Bank Restriction Act in 1797. The depreciation of the currency, however, which necessarily followed that measure, and the great proportion of deficient harvests which occurred between 1797 and 1812, (see Tooke *on High and Low Prices*,) to which we may add the extraordinary circumstances, Political and Commercial, in which the Country was placed, occasioned such a rise in the price of corn, as produced, in the minds of some landlords, a dislike to a fixed money-rent. The same circumstances had a very different effect on the farmers. A fixed money-rent was, in their opinion, the only way in which land ought to be hired. It was, however, the combined effect of these and other circumstances, that disclosed the imperfections of this mode of paying rent; and led, in many cases, to the adoption of another, which is to be next noticed. But before doing so, we shall submit a few remarks on a point connected with this subject.

Farming capital.

Some landlords, we believe, are under the impression that they suffered greatly from their lands having been let, during the period of high prices, on leases of nineteen years, at a fixed money-rent. This, we are much disposed to think, is a mistaken view. It ought to be recollected, that about the middle of the last century, the amount of farming capital was extremely small. It had, no doubt, been gradually accumulating from the period of the Revolution, about which time improving leases

Agriculture.

were, in a few instances, introduced; but even at the close of the XVIIIth Century, it was very far from being adequate to the improvement and cultivation of the Country. It was during the period from 1780 to 1812, but especially during the latter half, that the farming capital, in the Northern parts of the Kingdom especially, received an accession which made it nearly equal to the proper cultivation of the land. And this accumulation of capital, let it be observed, arose chiefly from the tenantry holding leases for a period of years at a fixed money-rent. During that period of Agricultural prosperity, the Art was prosecuted with a degree of spirit and enterprise unexampled in this, or perhaps in any other Country. As a natural consequence, it attracted a great number of individuals from other professions, which, with the increased capital in the hands of the tenantry in general, produced an immense competition for farms, and ultimately raised rents to the highest pitch the lands were worth, even if the average prices of the fourteen years preceding 1812 had continued. During that period of excitement, the landlords, as the leases expired, reaped a considerable share of the advantage in the rise of rent obtained, and, perhaps, still more from the improvements effected by the tenantry on their estates. But they are deriving, and will continue to derive, a still greater benefit from the increase of farming capital and skill, which those years of prosperity called forth. The progress then made in the knowledge of the Art, and the additional capital acquired, have, beyond all doubt, enabled the tenantry to pay during the last ten or twelve years, at least from fifteen to twenty per cent. more rent, than they could have done from 1750 to 1800, supposing the prices of farm-produce to have been the same at both periods. In this way, there is reason to think, that the landlords are more than remunerated for any sacrifice they made during the high prices; and there can be little doubt, that Agriculture has, at the same time, been essentially and permanently benefited.

greatly increased between 1780 and 1812.

Consequent increase of rent.

Advantages of a fixed money-rent

From what has been said it is obvious, that a fixed money-rent, though it does not appear to have been attended with any loss to the landlords, has proved highly beneficial to the interests of Agriculture; still it must be admitted, that the late alteration in the value of the currency, and the changes which have been made on the corn laws, have had the effect of putting the capital of those tenants paying a fixed money-rent, in the power of the landlords; and though in most instances, we believe, the proprietors were too liberal-minded to avail themselves of the advantage thus obtained over their leaseholders, it is a state of things, against the recurrence of which, a provision, as far as possible, should be made.

Greater advantages of a fixed quantity of produce.

On the whole, though a fixed money rent appears much preferable to a *fixed proportion of the produce*, there seems great reason to think, that a fixed *quantity* of produce convertible at the average prices of each year, is less objectionable than either of the modes noticed; and upon this we shall offer a very few remarks.

A fixed quantity of produce has the important advantage of providing fully and completely against variations in the price of corn, arising either from changes in Commercial policy, or in the value of the currency; and at the same time has *no effect whatever* in damping the exertions of the tenant, as he knows every bushel he can produce beyond the landlord's share is entirely his own. These are advantages of great value even in a National point of view, inasmuch as they secure the landlord, in the first place, in obtaining the value of his lands *during* the lease; and secondly, go far to prevent any great destruction of farming capital. This mode does not, indeed, provide for the difference of price arising from more or less favourable harvests. This, however, can be remedied, to a certain extent, by fixing a maximum and minimum price—the former, to guard the interests of the tenant, in years of extraordinary scarcity—the latter, to protect the landlord from the lowness of prices arising from unusual abundance. Great judgment, however, is required in fixing the maximum in elevated and exposed situations, as an error in this particular might lead to the ruin of an industrious tenant in unfavourable seasons. With these checks judiciously applied, though the rent in any one year may not be precisely what it ought to be, still the disparity betwixt it and the prices, will not in any case be such as to depress the tenant, to the extent of either checking his enterprise, or diminishing his means for the profitable cultivation of his farm. Neither will the interests of the landlord at any time suffer materially. Indeed, a fixed quantity of produce convertible at the average market prices, seems to us to protect the interests of both parties, as far perhaps as is practicable. The same principle, in our opinion, might be beneficially adopted in fixing the rent of pasture-lands, provided the same means were taken to authenticate the prices of cattle, sheep, wool, and dairy-produce in each County, as is taken for ascertaining the prices of corn. This subject is deserving of serious consideration, and the plan, with little difficulty, might be carried into effect. We shall only say in conclusion, that the view here taken, has been borne out by many years' experience, in several parts of the Country, in which that mode of fixing the rent of corn lands has been in operation.

IV. The *fourth* inquiry is,—"Whether ought there to be any stipulations in a lease, with respect to the management of the farm; and if there should be stipulations, what ought they to be?"

Necessity of restrictive clauses in leases.

Although the stipulations in leases must of necessity vary according to the circumstances of each particular case, we do not think they can in any one instance be dispensed with. In those districts of the Country in which the principles of Agriculture are little understood, restrictive clauses are, during the whole lease, indispensable: *first*, to protect the interest of the landlord; and *secondly*, in some degree to lead the tenant to a better system of husbandry. There is little chance, however, of a tenant of skill and capital adopting an injurious course of management, during the first half of a nineteen years' lease; but in the latter half, the interests of landlord and tenant begin to diverge, and in the last year or two, become nearly opposed to each other:—it being then the interest of the landlord to have the lands in the highest possible state of cultivation, so as he may obtain the greatest rent they are worth upon the renewal of the lease; while the interest of the tenant is obviously to extract from the soil all he can before his right of possession is at an end. A judicious person, in framing a lease, will keep this in view, and endeavour to construct the clauses as to management, so as to protect the just rights of both parties. And we are satisfied, that restrictive clauses at the end of a lease will be least objected to by those of the tenantry who have the clearest view of their own interest; for such persons know that a deteriorating system of cropping cannot be pursued

far, with advantage to themselves. Besides, when this practice is general, the loss sustained during the first four or five years of the new lease, is much greater than any paltry profits obtained by improper cropping, in the latter years of the old one. Indeed, the practice cannot be too strongly reprobated; because, instead of benefiting any party, it is extremely prejudicial to all, and not least to the tenants themselves. It would be easy to establish this beyond all question, but it would lead to details which might neither be interesting nor useful in a general treatise.

Objects of restrictions

The principal object, then, of all clauses in leases, ought to be, to put it in the power of the tenant to manage and cultivate his farm upon the most approved principles known at the time of his taking possession, and to allow him to avail himself of any improvements which may take place in Agriculture, or otherwise, during the currency of the lease; and on the other hand, to give security to the proprietor, that his lands will be properly cultivated during the whole period, but especially during the last five or six years. It is, as formerly stated, impossible to say what the clauses of a lease ought to be in any particular case, without a knowledge of the whole circumstances connected with the farm; and it is equally impossible to frame any conditions which would be generally applicable. All that can be done, is to state the principle upon which such restrictive clauses should be inserted.

Their nature.

In every case, a landlord must, either of himself, or by the advice of those in whom he can confide, determine the proportion of exhausting crops which his land can profitably carry,—keeping in view the nature of the soil, climate, situation, and other circumstances,—and must frame the restrictive clauses so as to prevent that proportion from being exceeded, and to provide for a due quantity of putrescent manure being regularly applied. Although many objections might be stated to binding a tenant to crop and cultivate his land according to a specific plan, even during the latter years of the lease, we are of opinion, that any departure from good culture for four or five years out of nineteen or twenty-one, is so detrimental to the interests of all parties, that it ought by all means to be prevented. And, perhaps, no better general principle could be applied, than that the tenant should not be allowed to depart from the system he has pursued during the previous years of the lease.

Object in letting.

V. With these observations, we shall next advert to the *fifth* query, namely, "Whether ought a farm to be let *publicly* or *privately*? and whether ought the highest bidder, supposing him to be in other respects unobjectionable, always to be preferred?"

The object which ought to be kept in view in letting lands, is, to obtain their fair value from tenants of respectability, who are possessed of adequate skill and capital for the proper management of their farms. That mode of letting them, therefore, ought to be adopted, which affords the best chance of attaining these objects. To us, the chance of accomplishing the end in view seems much greater by private than public letting. By the former, the proprietor can exercise a more deliberate judgment in regard to the merits of the candidates, and the tenant in regard to the value of the farm.

Advantages of private letting.

A higher rent may no doubt be obtained at an auction, but this is no good reason in favour of such a method, as there are few things more detrimental to Agriculture than over-rented farms. Tenants so situated, seldom make exertions, or display a spirit of enterprise, consistent with their own interest, or the interest of their profession. As farms are, in our opinion, much more likely to be over-rented, and to fall into the hands of an inferior description of persons, by being let by auction, than by receiving private offers, we would, on that account, prefer the latter mode. At a public auction, there is a degree of excitement which sometimes leads a bidder to go further than his judgment in his cooler moments would dictate; besides, some are apt to offer, trusting to the knowledge of the preceding bidder rather than to their own.

As to whether the highest bidder ought always to be preferred, we are decidedly of opinion, that capital, intelligence, and skill, ought, in most cases, to have a preference; and there can be no doubt, that the landlord who is guided by this rule, will, in general, consult his own interest, and the interest of Agriculture.

VI. As to the last point, namely, "Whether houses and buildings ought to be erected by the landlord or tenant? and if by the latter, how should he be indemnified for them?"

Buildings ought to be erected by landlord.

It appears to us, that the buildings and houses ought, in general, to be erected by the landlord. The sum necessary for this purpose, is more than the tenant can be expected to possess beyond what is required for the stocking and improvement of the farm. Besides, such erections can be made by the landlord at as little expense as by the tenant; and consequently, when executed by the former, the effective agricultural capital of the Country is greatly increased. It is worth observing, perhaps, that the landlord, having a permanent interest in the property, will take care to erect buildings, both as to stability and extent, suitable to the general uses of the farm: whereas, it can scarcely be expected, that a tenant, having only a temporary interest, will be guided by the same views.

Bad effects of the metayer system on the Continent.

We might have expanded the considerations under the third head to a much greater extent, and taken a review of the *metayer* system, as it operates in many parts of the Continent, in which the farmers pay a fixed proportion of their produce to the landlord in name of rent. This has been pronounced by Mr. Arthur Young "the most detestable of all modes of letting land," in which, after running the hazard of many heavy losses. "the defrauded landlord receives a contemptible rent; the farmer is in the lowest state of poverty; the land is miserably cultivated; and the Nation suffers as severely as the farmers themselves." Notwithstanding the numerous changes introduced by the Revolution, this objectionable scheme prevails in more than the one half of France, and throughout the greater part of Italy. We need not add that Agriculture has made no progress in either Country, in the midst of numerous improvements derived by all other pursuits from the general cultivation of the Physical Sciences.

Definition of Commerce.

COMMERCE is the interchange of commodities, whether manufactures or agricultural products, for money or for other commodities: in the latter case it is called *Barter*. Some persons consider that all buying and selling carried on among ourselves ought to be called *Trade*, and that the name of Commerce should be appropriated to our foreign transactions; but this distinction seems hardly justified, either by the etymology of the respective words, or by the practice of merchants, with whom "foreign trade" is as frequent, or rather a more frequent expression than "foreign Commerce."

We propose for the principal subjects of the present Essay,

1. A Historical sketch of Commerce; and
2. Its condition in the present Age, as well in England as on the Continents of Europe and America.
3. Connected with these, will be a series of observations on collateral subjects; such as money, or the circulating medium of Commerce; the mines of gold and silver, particularly in America; and the use of Bank paper during the last hundred years.

Origin of Commerce.

The advantage of an interchange of commodities, of one person supplying what was needed by another, must have been obvious in the earliest stages of Society. Such interchange, however, must have been on a very insignificant scale among Tribes living in the state of hunters, and seeking their subsistence, not from domesticated animals, but from the chase and the precarious spoils of the forest. Such appears from Scripture to have been the state of the central part of Asia. in the Ages following the Flood; in the time of Nimrod and other predecessors of Abraham. It was the condition also of the aboriginal Greeks before Cadmus and other foreigners, arriving from the East, accustomed the natives to useful Arts; and it was the state of the chief part of England on the first invasion of the Romans. Such at the present day is the case of the Indians of North America, who roam over the vast tracts to the West and North-West of the Mississippi, obtaining by the chase quantities of furs to exchange with English and American traders, but living in other respects in great penury, and having very few commodities to barter among each other.

The state of Pasturage.

In the next stage in the progress of Society, the state of Pasturage with little tillage, the interchange of commodities is still on a very limited scale. Referring again to the Book of *Genesis*, we find this to have been the state of Chaldæa and of part of Syria in the Age of Abraham, about four centuries after the Flood, or nineteen centuries before the Christian Era. Population, although increasing, was still very thinly spread, and property became considerable in the hands of only a few, the bulk of the community being, as expressed in Scripture, "bondmen and bondmaids;" in other words, servants and labourers paid not by wages, but by maintenance. The Northern part of Arabia must have been very thinly peopled in the time of Jacob, yet his flocks, like those of his brother Esau, increased, "so that they could not dwell together: the land could not bear them because of their cattle." The consequence was that Esau removed his family, his cattle, and all his substance to a distance, and dwelt on Mount Seir. Similar to this was the state of Scythia in ancient times; and such, down to the present day, is the condition of the vast regions of Tartary. In this stage of Society families are almost always removing in quest of new pastures; there are hardly any towns, and but few villages; each household is consequently obliged to supply its own wants, whether in provisions or clothing; and the exchange of commodities is trifling, as it always must be until, tillage being introduced, population becomes stationary, and, in some degree, concentrated.

The Agricultural state;

We next arrive at the Agricultural state; the time when individuals and families drew together in hamlets, villages, and, eventually, in towns. Employment then becomes divided; persons follow separate trades; and the products or workmanship of one are exchanged for those of another. Intercourse is then carried to such a length as to be entitled to the name of Commerce.

Countries in which Commerce first became considerable.

If it be asked in what part of the World was the exchange of commodities first carried to any considerable extent? we answer in Mesopotamia, Egypt, and the more fertile Provinces of the North of Arabia. For this we have the direct authority of Scripture, as well as the indirect but powerful evidence afforded by the local advantages of certain tracts of Country, such as those adjacent to the Euphrates and the Nile. In warm climates the great desideratum in cultivation is a supply of water; and population first becomes dense in districts which possess such a supply in abundance, whether from rivers periodically overflowing their banks, from streams descending from high grounds, or from a soil yielding water in wells at a slight depth from the surface. Now Civilization and Commercial intercourse depend on, or rather arise from, density of population. It is to this we should ascribe the early improvement of Egypt, which even in the Age of Abraham, and still more in that of his grandson Jacob, had become so far a cultivated Country, as to be able to afford a supply of corn to its neighbours when scarcity unfortunately prevailed among them. To a similar cause, we mean the dense population in Chaldæa, consequent on the overflowing of the Euphrates, and the ease with which the level tracts adjoining to that river were laid under water, we are to attribute the grandeur of Babylon and the power of the Assyrian Empire.

Commodities conveyed by land-carriage.

Almost all trade in those remote Ages was carried on by land, and as there were neither roads for wheel-carriages, nor bridges over rivers, merchandise was transported on the backs of camels and other beasts of burden. Traders proceeded generally in companies, for the sake of mutual aid and protection, exactly as is practised in the present day, and on a larger scale, by Caravans. It was to a company of Ishmaelites (Arabs,) carrying spices from Gilead to Egypt on camels, that Joseph was sold by his brethren, about seventeen centuries before the Christian Era. The practice of conveying merchandise on the backs of animals still prevails in Countries in which an Englishman would expect that roads might long since have been made and wheel-carriages introduced. It is general not only in the thinly

peopled Provinces of Brazil, Peru, Buenos Ayres, and Columbia, but in Mexico, the least backward part of Spanish America. That healthy and fertile region, now possessed by Europeans during three centuries, can, even at present, boast of no more than three or four highways fit to be traversed by wheel-carriages; and all the goods transported through its territory, whether manufactures imported, or produce sent down to the coast for export, are conveyed on the backs of mules and horses, a distance of several hundred miles.

Intercourse by water.

The earliest attempts to convey commodities by water were made on rivers or inlets of the sea, by means of canoes and rafts. Between these, the simple contrivances of a rude Age, and the bark fitted to proceed to the open sea and to encounter the winds and waves, the difference is very great. Ship-building and Navigation are complicated Arts, requiring both mechanical dexterity and a stock of knowledge which can exist only in a society considerably improved. Hence Commercial intercourse by sea is long in beginning, and for a time is carried on on a very limited scale. With the nations of antiquity this slowness was unavoidable, unacquainted as they were with the use of the mariner's compass, and limited in their knowledge of Geography. It was the custom of their seamen to keep within sight of land, and on the occurrence of stormy weather, not to stand out to sea, but to seek shelter in a bay or inlet. This practice, so contrary to that of modern navigators, arose from two causes; the smallness of their vessels, which were often without decks, and the habit of propelling them as much by oars as by sails. By rowing towards a bay or the mouth of a river, they were almost sure of entering it, whatever might be the direction of the wind; and the shallow draught of their barks admitted of their being run ashore beyond the reach of the tempest. Summer was the only fit season for such awkward mariners: to have gone to sea in the Winter months would have been accounted a great imprudence.

Navigation of the Red Sea

One of the earliest branches of Navigation was that carried on along the Red Sea, for the transport of commodities from Arabia to Cosseir, or the port, whatever it was, which served as an entrepot for the trade of the Red Sea with Thebes in Upper Egypt. The merchandise landed at Cosseir is commonly considered to have been the produce of India, imported, in the first instance, into certain seaports of Arabia, near the mouth of the Red Sea. But whether the products were Indian or Arabian, the traffic appears to have been considerable, and to have been one cause of the great population and extent of Thebes; an extent proved equally by the descriptions of ancient writers, and the magnitude of the still remaining ruins. The other causes of the prosperity of Thebes were that the fertilizing effects of the overflowing of the Nile were turned to account in its vicinity at an early Age. The breadth of cultivated ground in Upper Egypt appears to have been greater in those days than at present, the flying sands from Libya having, in the course of so many centuries, covered a part of the Valley of the Nile, particularly to the West of the river. Thebes was centrally situated in regard to the Northern and Southern divisions of that long and fertile valley; the Nile being easily navigated, connected them, so that this city was both the residence of the Government, and a station for the deposit and exchange of the commodities of the upper and lower divisions of the Kingdom. Subsequently, the seat of Government was transferred lower down the Nile to Memphis, (nearly on the site of Cairo,) in consequence, probably, of the augmented population of the Delta, and perhaps of the advantage of comparative vicinity to the North of Arabia, Phœnicia, and Syria, Countries which then constituted so large a portion of the civilized World.

Thebes in Egypt.

But the foreign Commerce of the Egyptians was at no time considerable. Their Religion discountenanced Navigation, and their Government restricted their intercourse with foreigners, somewhat in the manner in which that of the Chinese acts with regard to Europeans. The Phœnicians, on the other hand, were altogether Commercial in their habits as in their laws. Sidon, the first seaport of consequence mentioned in History, was distant only one hundred and fifty miles from the mouths of the Nile, and the foreign trade of Egypt was carried on by Phœnician mariners, first of Sidon, afterwards of Tyre. The Phœnician coast abounded with timber for ship-building, and its position was central for intercourse with such parts of the World as were then advancing in civilization. Confined at first to the adjacent Countries, *viz.* Egypt, Cyprus, Cilicia, the Phœnician navigators ventured in the course of time to take a wider range, visiting and planting colonies in Crete, Greece, Libya, and Sicily. In all these Countries the inhabitants were uncivilized, and were indebted to the Phœnicians for the rudiments of knowledge and the introduction of the useful Arts. These Countries were situated to the West: but there was also a regular traffic between Phœnicia and the Southern part of Arabia, carried on partly by land, partly by water; by land from Phœnicia to Elath, a port in the Northern or upper part of the Red Sea; and the remainder of the distance by shipping navigating that sea.

The Phœnicians.

Judæa, in the reigns of David and Solomon.

The next Country entitled to notice in a Commercial sense is Judæa. The Jews progressively increased in number during the long period (seven centuries) which elapsed between their settling in Egypt and the era of their greatest prosperity, the reigns of David and Solomon. In those reigns they made the conquest of Idumæa, a Province extending along the North-Eastern shore of the Red Sea, and seeing the wealth possessed by their Phœnician neighbours, they became desirous of engaging in foreign Commerce. This desire was facilitated by the friendly understanding which so long subsisted between the rulers of Tyre and David and Solomon. The latter sent yearly to Tyre quantities of corn and oil, the produce of Judæa, receiving in return foreign merchandise and a balance of gold and silver. The Jews being unaccustomed to Navigation, manned their merchant-vessels on the Red Sea by Phœnicians. The distant seaports with which they traded (Ophir and Tarshish) have not been recognised with certainty by modern Geographers, but the harbours Elath and Ezion geber, in which they landed their merchandise on returning, were situated in Idumæa. The foreign Commerce of the Jews, however, was of short duration, and seems to have been discontinued after the dismemberment of the Kingdom, which followed the reign of Solomon. Their trade in the Red Sea fell, doubtless, into the hands of the Phœnicians.

Commerce of Greece.

Greece indebted to Phœnicia and Egypt.

From Phœnicia and Egypt, Civilization and Commerce made their way to a quarter destined to become a copious fountain of instruction to the rest of the World. The easy access to Greece from the comparatively improved

Countries in the South and East, was a most fortunate circumstance. While the early annals of so many nations are replete with traditions of war and rapine, those of Greece bear testimony to the useful Arts introduced into their Country by foreigners, who became the founders of cities, the instructors of the rude inhabitants, the patrons of Agriculture and Navigation. These occurrences appear to have taken place for the most part about ten or eleven centuries before the Christian Era, a time at which Egypt had been for Ages in the enjoyment of a regular Government, and the seat of a considerable population. The improvements thus introduced into Greece, and the gradual increase of her towns, of Argos, Mycenæ, Athens, Thebes, Sparta, Elis, Corinth, brought the Country into the state in which it is so clearly described by Homer; who, whatever may be thought of his embellishments and exaggerations in some respects, is entitled to our full confidence when describing the limits of the respective territories, the state of Society, and the degree of Civilization existing in his time. To the accuracy of his Geographical descriptions an ample testimony is borne by the writer of all others the best qualified to judge, we mean Strabo.

Extent of her colonies.

The Age of Homer is generally placed about eight centuries before the Christian Era. The progress of improvement in Greece was afterwards checked by intestine troubles. The Dorians, a rude Tribe from the North, invaded the Peloponnesus, and succeeded in expelling from it the descendants of Pelops, the Princes of the second or third generation after those who are described by Homer as governing the chief part of the Peninsula. This invasion is called in History the Return of the Heraclidæ, and is considered to have taken place about eighty years after the war of Troy. The expatriation which followed was termed the Eolic migration, the exiles taking their course Northward in the direction of Thrace and Phrygia. In Athens the line of succession being altered in consequence of political events, the sons of the last King led a colony to the opposite coast of Asia Minor, where Ephesus and a number of other towns soon rose to importance; this was called the Ionic migration. Rhodes, eventually so important as a place of trade, was one of the earliest colonies of the Greeks; Cyrene, on the North coast of Africa, was another, while the almost equally remote island of Cyprus was settled partly by Phœnicians, partly by Greeks. But the principal foreign settlements of the Greeks were to the West, in Italy and Sicily. In Italy they founded successively Cuma, Rhegium, Tarentum, Thurium, Brundusium; in short, nearly half the maritime towns in the South. In Sicily they founded Syracuse, Agrigentum, Catania, Messina, Leontini, and a number of other towns, all on or near the coast, so as to keep up a Commercial intercourse with the Mother Country. Of these various migrations the earlier were compulsory, arising from political dissensions at home; but when the advantage of a change of residence became duly appreciated, succeeding removals took place voluntarily, and for the purpose of improving (as in the emigrations now making to our North American colonies) the circumstances of individuals. The motives and inducements were similar in either case: the territory of the parent States in Greece was limited; population was progressively increasing; and land, as in modern Europe, was high-priced, while in the colonies it was granted to settlers on very easy terms. Hence the rapid increase and eventual prosperity of several of the Grecian colonies; of Sybaris, Crotona, Tarentum, but in particular of Syracuse, which attained a degree of population and wealth beyond that of any city in Greece, not even excepting Athens.

In Asia Minor.

In Italy.

In Sicily.

The coast of Greece, number of inlets.

No Country is better situated than Greece for carrying on intercourse by Navigation. Its coast is of great length, and indented in many parts by the sea. A reference to the Map shows no less than ten extensive inlets similar to that of the Gulf of Corinth, each provided with one or more good harbours. Hence an early acquaintance with Navigation, if that name can with propriety be used in the case of barks without decks, propelled in general by oars, unprovided with anchors, and having only one mast which was raised or taken down according to circumstances. Such was the Greek marine in the time of Homer, and during the three centuries which elapsed between the Age of that Poet and the national improvements which preceded the invasion of Greece by the Persians.

Her inland territory.

The inland territory of Greece, mountainous and unprovided with roads, was not favourable to Commercial intercourse, or to the progress of National improvement as far as it depends on the union of several States into one. It was, however, highly favourable to the good government of small communities. Each town had its adjoining plain which supplied provisions and other requisites: the compact position of the population enabled them speedily to unite and cooperate if their freedom was threatened by a neighbouring State, or by an ambitious citizen at home. There was in those petty Republics, no distant Province supplying either a tribute or a military force which might be directed against the rights of the citizens. The public revenue proceeded wholly from the latter, and the military establishment being composed entirely of them, all had a similar interest in resisting an infraction of the Constitution. Hence arose the independence of the different States of Greece during several centuries, and an advance in Commerce and productive industry generally, greater than would have taken place under an absolute Government.

Her trade limited.

Still the Navigation and Commerce of Greece were very limited even in her most prosperous time: they took place chiefly between the Mother Country and the colonies planted in Italy and Sicily to the West; in Ionia in the East, and in Thrace in the North. The more distant voyages of Grecian traders were, in a Southern direction, to Egypt; in a Northern to Trebizond on the Euxine, and to the coasts of the Adriatic. In a Western direction they hardly ever ventured beyond Sicily, leaving the maritime intercourse with Spain, Sardinia, and the South of Gaul to navigators of a bolder character, the Carthaginians.

Alexandria in Egypt.

The extensive conquests of Alexander the Great gave rise to new arrangements in regard to the trade of Greece with Egypt and India. The obstinate resistance made to his arms by Tyre impressed him strongly with the resources of a maritime State, and as he ascribed the chief part of the wealth and power of Tyre to its trade with India, it was natural that, after destroying that city, he should seek to establish a naval station in a position adapted for carrying on both that and other branches of Commerce. Such a position he soon discovered near the Western mouth of the Nile, where Alexandria, founded by him, became, and continued for many centuries, the chief Commercial city in the East of the Mediterranean, and after the ruin of Carthage, in

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the World. Its situation was well adapted for the intercourse of Egypt with Greece, Italy, and other Countries; the Nile bringing to it the various products of the interior, and affording, on the other hand, a capacious inlet for imports. In regard to the trade with Arabia and India, Alexandria possessed, still more than Tyre, the advantage of a ready access to the Red Sea.

Of Carthage.

Carthage: magnitude of her trade.

Such was the Commerce of Greece in different Ages: at no time, it must be admitted, was it of so much importance as might have been expected from her extent of coast and advanced Civilization. Carthage, on the other hand, was altogether Commercial. Founded by a colony from Tyre, she soon equalled and eventually far surpassed the parent State. The sphere of Carthaginian Commerce was in the West of the Mediterranean; in Mauritania, Spain, the South of Gaul and Sardinia; likewise in Sicily and Libya. It extended also beyond the Straits of Gibraltar, in one direction to the coast of Morocco, in another to Portugal; or, as is often asserted, to the Western coast of France and the English Channel, where tin was a great object of attraction to the merchants. Tradition states that Carthaginian expeditions, equipped at the public expense, carried their discoveries greatly beyond these limits; to the Baltic in the North and to the remotest part of Africa in the South. But all that is known with certainty is that such voyages were attempted by order of Government; that Hanno was commander of the Southern, Himilco of the Northern expedition. Unfortunately the records of both have perished, and in the absence of other evidence the probability is that the African squadron did not carry its discoveries beyond the Canary Islands, in the 28th degree of North latitude. If we thus circumscribe the maritime progress of the Carthaginians, we can have no hesitation in restricting our belief in respect to that of the Phœnicians; and in treating as an amusing fable their alleged circumnavigation of Africa, related to Herodotus by Egyptian Priests.

Her political power.

We shall not, however, incur the risk of exaggerating when we ascribe to Commerce the origin of that power which enabled the Carthaginians to carry on extensive wars and to inflict severe blows on the rising greatness of Rome. Fortunately for the latter, their contests did not begin until Rome had extended her dominion over nearly all Italy, and possessed, in her citizens and allies, a population capable of speedily repairing the enormous waste of life sustained in the conflicts of Trebia, Thrasymene, and Cannæ. Of the progress of the Carthaginians in the useful Arts our means of judging are extremely imperfect in consequence of the destruction of their Capital; but from the number of their settlements, and the amount of their public revenue, there is reason to think that their productive industry must have been carried to a great extent: while the proportion of eminent men in the direction of their councils and armies, affords, to a certain degree, an argument in favour of their institutions. The charges brought against the Carthaginians by Livy and other Roman writers, are to be received with considerable distrust. Had not this State been unhappily cut short in its career, had time been given to it to improve the National education, to extend and mature its Commercial undertakings, there is every reason to conclude that it would have proved a great example of the benefits arising from persevering industry, and have materially conduced to the advancement of general Civilization.

Of Rome.

The Romans averse from Navigation.

The situation of the Romans in respect to Commerce was altogether different. Their military habits, and the want of a convenient seaport for their Capital, estranged them from naval pursuits. They constructed galleys for the sole purpose of opposing the Carthaginians, and their frequent losses from tempests, consequent on the unskilfulness of their mariners, rendered them averse from augmenting their navy. In the IId Punic War, the great operations were by land: hostile armies invaded the heart of their territory, and the expeditions requiring shipping, we mean those to Spain and Sicily, were of subordinate importance. At the close of this eventful struggle the power of Carthage was so much broken, and the dominion of Rome, first over Sicily, afterwards over Greece, became so absolute, as to give her the command of whatever naval power those Countries possessed, and to make it unnecessary to augment her shipping at home. This was still more the case after the course of events had added Asia Minor, Syria, and eventually Egypt, to the Roman Empire. The whole of the coasts of the Mediterranean was now subject to one Power; no maritime district ventured to attack another; and piracy, hitherto a great annoyance to Navigation, was effectually checked.

Such happily was the state of Roman Commerce during several centuries. An extensive trade was carried on between the Capital and the Provinces, in particular with Sicily and Egypt for corn; but the Government discovered no wish to transfer to Roman citizens the management of the shipping thus employed; they left it in the hands of its subjects at Alexandria and other remote seaports, because they saw no political motive for desiring its removal. The Imperial Rulers, strong in their military means, had no apprehension of any maritime city or district presuming, by means of its shipping, to resist their decrees; and they knew it to be impossible that a State so situated should cooperate with the uncivilized Tribes on the frontiers of the Empire, such as the Germans, Dacians, or Parthians, now the only enemies of the Roman name.

Navigation extended to the North of Europe;

This era of general Peace, particularly maritime Peace, was favourable to distant voyages, so that the most cautious inquirer may now give his belief to a Commercial intercourse between the Mediterranean and the South of England, carried on partly direct, partly overland through France. Such intercourse subsisted likewise with the German Tribes at the mouths of the Elbe and Weser, and, in a slight degree, with those in the Baltic, particularly in Prussia. In a very different quarter, we mean in the Red Sea and the Indian Ocean, considerable improvements took place in Navigation, in consequence of mariners becoming acquainted with the monsoons or periodical winds of that part of the World. Taking their departure from the mouth of the Red Sea on the setting in of the Western monsoon, they no longer confined themselves to the slow, circuitous method of sailing along the shore, but stretched boldly across the Ocean to the coast of Malabar; where, receiving their cargoes, they returned with the Eastern monsoon, so as to finish their voyage from the Red Sea to India and back, within the year. The uniform direction of

and to India.

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the wind supplied the want of the mariner's compass, and enabled them to reach their destined ports with little deviation. The number of vessels employed in the trade between the Red Sea and India was above one hundred; and as, in those remote Ages, Europe could supply few commodities useful to the natives of India, a yearly export of silver was required to purchase the homeward cargoes. The amount of specie thus sent from the West to the East is computed by Pliny at a sum equal to £400,000 sterling a year; a considerable amount certainly, but far below that which might be inferred from the lofty tone in which Dr. Robertson and others treat the Commerce with India.

Of the Middle Ages.

The Roman Empire invaded by the Goths and Huns.

We have now traced the History of Commerce to the period (the middle and latter part of the Vth Century) when the Northern Barbarians made their way into the Roman Empire; into Gaul, Spain, Italy, and Africa. The consequences, in a Commercial sense, were very unfortunate, suspending in each of these Countries the free intercourse so long enjoyed under a common Government. The Empire was now divided into a number of separate and unconnected States; Navigation became unsafe; the roads, made with care by the Romans, were neglected. The increase of the population of towns, the best evidence of the extension of productive industry, was suspended. Many towns were plundered; others were subjected to repeated contributions; property was unsafe under the control of rude and lawless invaders; manufacturers and artisans withdrew or rather fled with their families to places of safety. Hence the origin of Venice in a very singular position; the town being built on a collection of small islands, separated from the main land by shallow lagoons. It was thus protected from attacks by land, and, in some degree, by sea, as vessels above a certain size could approach the town only by channels, from which it was easy for the inhabitants to remove the poles or buoys which pointed out the intermediate sandbanks. The result fully justified the confidence of the founders of Venice in its means of defence; for though its wealth soon became so extensive as to offer great temptation to predatory bands, it defied their violence, and never, until the present Age, saw a hostile force within its walls.

Venice founded; its singular position.

Constantinople.

Constantinople, in like manner, was long preserved amidst the general invasion of the Empire. Protected by its fortifications, it continued an asylum for the property of merchants, a centre for the intercourse of the seaports in the Mediterranean and Euxine which still carried on trade. Its communication with Alexandria was maintained even after the loss of Egypt; and its traffic with Venice proved one of the main causes of the increase of that city. With India also it preserved intercourse to a certain extent, after the occupancy of Egypt by the Saracens had interrupted the usual channel of navigation by the Red Sea. The route then adopted by merchants was very circuitous: goods were transported from the coast of Malabar to the Indus; they were made to ascend that river as far as was practicable, and thence carried by land to the Oxus, down the stream of which they were conveyed to the Caspian Sea. After traversing that sea, the vessels entered the Wolga and sailed up its stream, until they reached the part adjacent to the Don: there the goods were unshipped, carried by land to the banks of the Don, and embarked in boats which proceeded to the mouth of that river in the Euxine, where vessels from Constantinople waited their arrival. So long and expensive a conveyance was suitable only to goods of which the value was great compared to their bulk; to silks, cottons, and spices, which have at all times been the principal exports from India.

Intercourse with India by the Caspian Sea.

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Another and a much more direct route for merchandise from India, was by sea from the coast of Malabar to the Persian Gulf, and thence up the Tigris to Bagdad, or up the less rapid stream of the Euphrates to latitude 34°. There the goods were landed and conveyed across the Desert first to Palmyra and afterwards from that city to the coast of the Levant. To this trade we are inclined to ascribe the extent and wealth of Palmyra; a magnificent city raised in the midst of Deserts. The chief objection to this route was the danger to the caravans from the Arabs; and as that hazard could not be removed in such a Country and under the political circumstances that ensued, the merchants trading with India gladly embraced the earliest opportunity of resuming the former route; *viz.* from Malabar to the upper part of the Red Sea, thence by land to the Nile, and down that river to Alexandria, whence the merchandise found its way to many distant ports, in particular to Constantinople, Venice, and Pisa.

By Palmyra.

Seaports in Italy: Pisa.

Among the chief seaports in Italy during the Middle Ages, Pisa, a place of great antiquity, took a lead, so early as the Xth Century. It was built on the banks of the Arno, not at the mouth of that river, but about three leagues inland, a precaution often adopted in a rude Age, to avoid or at least to lessen the danger of attack from the sea. A rich and spacious plain surrounds the town, which is of considerable extent, its walls having a circuit of six miles. The Arno is here a full, majestic stream, dividing the town into two nearly equal parts: the quays are spacious, extending along either bank from one side of the town to the other. It had become a seaport of consequence before the Crusades, and like Venice and Genoa increased its shipping considerably at the time of those expeditions. The chief sphere of its Commerce was the Western coast of Italy, the shores of Sardinia, Corsica, and Sicily. It kept up an armed force of galleys, and held as a Commercial town a rank equal to Genoa, until the population and wealth of the latter increased in the XIIIth Century. Circumstances are now greatly altered; in the early part of the XVth Century Pisa became subject to Florence; and Leghorn, being in the immediate vicinity of the sea, has gradually absorbed the foreign trade of this part of Italy.

Genoa.

Genoa, in like manner, is a town of old date, having been a place of trade before the year 1000, and becoming, some time after, the Capital of an extensive territory; the petty States around incorporating themselves with it for the sake of protection. Acting in concurrence with Pisa, Genoa recovered Sardinia from the Moors, obtained subsequently several valuable settlements in the Levant, and had factories or mercantile establishments at Constantinople for the deposit of goods imported from Asia Minor and India. She acquired also the Island of Corsica, and in Sicily held Syracuse on account of its excellent harbour. This favourable career received, however, a check by a maritime war with Venice in the latter half of the XIVth Century which proved very injurious to both. In the next century Genoa was disquieted by party contests among her principal citizens. These were of long continuance, and had

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attained a great height, when, towards the beginning of the XVIth Century, Andréa Doria, so well known as a naval commander, found means to effect a reconciliation among his fellow-citizens.

Genoa is favourably situated for trade, having a harbour in the form of a half moon, above half a mile in diameter. It is enclosed by two strongly constructed moles, one on the East, the other on the West: it can admit vessels of great draught, and is protected from most of the prevailing winds. On the land side, also, Genoa has considerable means of defence, the town standing on the ascent of a hill the upper part of which is surrounded by a double wall: the outer wall is of great extent, and the inner has a circumference of no less than six miles. Viewed from the sea, the town and its environs present the form of an amphitheatre and have an appearance of great magnificence.

These Cities, together with Venice, were the chief seaports of the North of Italy during the XIIth and XIIIth Centuries, when the North and West of Europe sent forth so many successive expeditions to the Holy Land. The rude warriors engaged in these enterprises, accustomed to see the lower orders in the humble condition of serfs, and acquainted with hardly any buildings but a Baronial castle and its adjoining village, were struck with admiration at the regular streets, the intelligent population, and the numerous shipping of the Italian seaports.

Towns enfranchised. In Italy.

The same superiority was manifest in the North and West, on a smaller scale, in a number of the inland towns of Italy, which had by this time obtained their independence and formed themselves into communities, with a regular municipal Government. Some of the larger towns acquired their independent Constitution by Grant or Charter from the Emperors of Germany, for which they paid largely; others, at a less expense, by Grant from a neighbouring Prince; while a third class of towns, more distant from a controlling power, declined to acknowledge any superior, and assumed a Constitution of their own accord.

In the Netherlands.

Of the towns in the Netherlands, several had by this time acquired independence, and the example thus given in the two most improved Countries in Europe was soon followed in France. There, the Sovereign reigning in the early part of the XIIth Century (Louis *le Gros*) set to his Barons an example of enfranchising all towns and considerable villages situated in the domain of the Crown.* He abolished all marks of servitude among the inhabitants of those towns and villages, empowering them by Charter (*charte de communauté*) to form themselves into Corporations to be governed by a Council and Magistrates of their own choosing. The Magistrates were invested with the right of administering justice in the town and adjoining district; of levying assessments, and of training to the use of arms the militia of the town, that they might enter on service when required by the Sovereign. The example thus given in France by the King was followed by many of the Barons, who, impoverished by the Crusades and other expensive enterprises, gladly embraced an opportunity of recruiting their finances by so easy a process as the sale of Charters to the towns within their territories. In less than two centuries the towns in France, small as they in general were, became so many free Corporations, instead of places devoid of jurisdiction or privileges. A corresponding course was pursued about the same period in Germany, where the chief trading towns, such as Ulm, Augsburg, Nuremberg, and Frankfort, were declared "free cities of the Empire." In Spain and England immunities were granted on a similar plan to the chief towns and villages; as was done somewhat later Scotland, in those days a very backward and thinly peopled Country.

In France.

In Germany.

These Historical facts enable us to judge of the origin, progress, and eventual extinction of the Feudal System. The leaders of the uncivilized Tribes which overthrew the Roman forces, and occupied successively the different Provinces of the Empire, rewarded their followers by extensive Grants of land over which they ruled as petty Sovereigns, there being in fact hardly any other authorities, Military or Civil at a distance from the Capital. The population was then almost wholly agricultural; the villages were few in number and the towns still fewer. In the course of time, particularly under Charlemagne, the population of towns and villages increased and a degree of improvement took place; so that by the XIth and XIIth Centuries a number of places had become capable of forming Corporations, and desirous of having the management of their local concerns. By the Grants or Charters already mentioned, the Prince or Baron on whom the towns were dependent, conferred the rights which they desired; which, by exempting mercantile intercourse from arbitrary imposts, gave security to property in transit, and proved highly conducive to the extension of trade.

Constantinople: its Commerce and wealth.

The admiration excited in the Crusaders by the chief towns of Italy was felt in a still stronger degree at the sight of Constantinople, the only Capital which had escaped the ravages of the Barbarians. The Franks, as the natives of the West of Europe were termed in the Levant, saw there a city on a great scale, having, as they described it, "extensive walls, lofty towers, superb churches, and splendid palaces." "We could not," says a Historian of the Crusades, "have believed that there was in the world a city so beautiful and so rich." Constantinople, in the XIIth and XIIIth Centuries, was still the seat of various manufactures, and carried on a considerable trade with foreign parts; with Egypt, with India by way of Alexandria, with Venice, Pisa, and Genoa. The intercourse thus maintained between the Italian seaports and the Greek metropolis, during the Middle Ages, was one of the principal links by which a knowledge of useful Arts was preserved, and the productive industry of the Ancients connected with that of the Moderns. The Crusades had at least one good effect, that of extending national improvement and of imparting to the unlettered inhabitants of the West and North an idea of the Civilization of the South and East of Europe.

Venice: its gradual increase.

The increase of Venice was very gradual, and its ultimate greatness was the consequence, not, as is vulgarly supposed, of any single cause, such as the trade with Alexandria for India goods, but of the natural growth of population and capital in a prudently managed community. In the XIIth and XIIIth Centuries, the era of the Crusades, its power had become such as to enable it to occupy several islands and maritime districts of the Greek Empire favourably situated for trade, in particular the Ionian Islands, the Morea, and Candia. These remained long in possession of Venice, while on the main land of Italy she possessed the rich territory in which are situated Padua, Verona, and Vicenza, as well

* See History, ch. lxxiii. p. 615.

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as Friuli, a fertile and extensive Country to the East, acquired about the year 1420.

Its manufactures.

The manufactures of Venice, though not extensive in any one branch, were, as a whole, great from their variety; they comprised silks, lace, jewellery, stuffs of gold and silver, mirrors, and, to a certain extent, woollens and linens. An enumeration of articles so different and so unconnected with each other, may seem strange to an English reader, accustomed to see a particular manufacture conducted on a great scale, but confined to the districts which are fitted for carrying it on by possessing local advantages, such as an abundance of fuel, an extensive communication by water, or the growth of the raw material in the vicinity. But in former times circumstances were very different; a single manufacture would not have been worth following by many persons in one town, so small was the consumption in a given district, so difficult the conveyance of any bulky articles to a distance. Hence a multiplicity of manufactures were established in one city, such as Venice, although the materials for them were not produced in its vicinity; they were brought to it from various foreign ports, and collected on one spot, an advantage which, joined to the presence of a considerable population and a consequent large supply of workmen, outweighed the cheaper living of Provincial towns, cut off, as the latter generally were, from the requisite supplies, by want of capital, bad roads, and insecure communication.

Its policy.

The form of Government in Venice was at first democratic, but assumed an aristocratic character in the XIIIth Century, after extensive trade had caused the accumulation of large property in a certain number of families. In regard to foreign States, the policy of Venice was generally pacific; yet it had to sustain, in 1508, the attack of a formidable Coalition, named the League of Cambray from the town in which the aggression was planned. Nor could Venice avoid taking a part in the repeated contests between France and Austria, for the rich territory of Lombardy; contests which were carried on with great eagerness in the reigns of the Emperor Charles V. and of Francis I. The condition of Venice at that time bore a considerable resemblance to that of Holland a century later. Pacific herself, her frontier was threatened by the struggles for the Milanese, a Country not unlike Belgium; and though feeble in native soldiers, she was strong by the power of subsidizing; for her Government raised money at very moderate interest, while powerful Sovereigns were obliged to pay a very high rate, or to desist wholly from their attempted loans.

The naval force of Venice in those days consisted in galleys, and was kept up to protect her traders against the Barbary Corsairs as well as to resist the attacks of the Turks on Candia, the Morea, and other territories in the Levant.

Its Bank; origin of the funding system.

The Bank of Venice, the earliest establishment of the kind in Europe, and which has served as a model to so many Banks in other Countries, was founded in the middle of the XIIth Century. The merchants of the North of Italy, being the first in modern Europe who became considerable in trade, were the authors of many valuable inventions and improvements, such as the use of bills of exchange, and the practice of keeping mercantile books by double entry. To these was added a system, fair in itself and beneficial so long as it was followed in moderation, but the abuse of which has entailed a heavy burden on several Countries, above all, on England—we mean the Funding system; the practice of creating and selling Government stock. Its origin was as follows. The Government of Venice having found it necessary to borrow money from the public Bank, and apprehending that it would not for many years be able to repay it, adopted the plan of making it transferable from one person to another. This arrangement was judicious, and prevented loss or complaint on the part of the creditors of the State; the value of the stock was maintained, because the credit of the Government was good, and it found a ready sale on the Exchange because the number of persons desirous to purchase stock was fully equal to those who from time to time were inclined to sell it. This practice, adopted in Italy so early as the XVth Century, was followed by the Government of Holland after the year 1600; by that of England not till 1688. These dates are useful in distinguishing the respective periods at which monied capital became abundant in each Country; for the Government of each was, we may be assured, disposed to have recourse to this tempting expedient long before, and was held back only by the limited means of their subjects.

Spain: size of her towns in the Middle Ages.

The population of Spain in the Middle Ages, though scanty on the whole, was, to a certain extent, concentrated in towns. This arrangement was necessary for mutual protection in the wars with the Moors, the open country being unsafe when hostile incursions were frequent, and a town being the only fit station for the troops, (chiefly cavalry,) which were kept either to repel an attack or to carry devastation into the Moorish territories. There are no authentic returns of the population of Spanish towns in the Middle Ages, but we can by no means agree with the writers who, like Dr. Robertson, lend credence to the traditionary reports of their magnitude. The task of rearing a family is in general so difficult that, in the absence of correct returns, we may safely take for granted that the progress of population has been slow, except under peculiarly favourable circumstances; such as those of a colony having both an ample territory to cultivate, and a connection with an old Country for a supply of settlers and the sale of its products. Such was the case of the Greek colonies in Ionia and Sicily, and such at present is the case of the United States of America. Spain had no such advantages; neither had she, like Italy in the Middle Ages, an agriculture of old date, nor, like the Netherlands, the means of easy intercourse by water. Whatever we know of the History of Spain tends to show that there, as in most Countries of Europe, population increased very slowly during the Middle Ages; and as there is very little truth in the alleged drain of her inhabitants to America, the only safe inference is that in former times, as at present, Spain was thinly peopled. Her surface is mountainous, and her agriculture often suffers from want of water; a want likely to be strongly felt in times when, from deficient machinery, irrigation was much less practised than at the present day.

The trade and manufactures of the Spaniards appear to have been confined to the supply of their own wants; their foreign intercourse was very limited. Cadiz and Madrid, now their chief cities, were in those days inconsiderable. Seville was of more importance, but whoever examines attentively the position of that town, the limited navigation of its river, or the general poverty of the times, must be satisfied that the reports of its former population and splendour were greatly exaggerated. Still more does this hold in regard to other towns, such as Tortosa,

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The Hanse Towns.

The Association of the Hanse Towns was formed in the XIIIth Century, and subsisted above three hundred years. Its object was to provide security for mercantile property at a time when the different Governments of the North of Europe, stinted in their financial means, and seldom guided by fixed rules, afforded such security in a very limited degree. The first point with the Confederates was to repress the seizure of merchant-vessels by pirates and the robbery of goods conveyed by land; the next was to obtain justice in regard to the claims of merchants in Courts of Law. In those rude times it was the custom to consider a stranded-vessel and her cargo as lost to the owners, and as having become the property of the Baron whose lands lay along the part of the coast on which the wreck took place. It was further customary, when a merchant died at a distance from his home, for the Magistrates of the town or district in which he died, to put an arrest on his property, the removal of which became a matter of great difficulty. And if he died in a strange Country, indebted to any of the inhabitants, it was not unusual with the Police to imprison the first of his Countrymen they could find and oblige him to pay the debt.

Origin, The town which took the lead in forming this Association was Lubeck, the trade of which had become considerable in the XIIIth Century, chiefly from its position. Situated at the South-Eastern point of the Baltic, it was the natural entrepot for the trade of Prussia, Poland, and Livonia with the North-West of Germany; in the same manner as Hamburgh, from its ready access to the North Sea, was the fit port for communicating with the Netherlands and England. The distance between these towns by land being small, (only forty miles,) frequent conferences took place in regard to their mutual interests, and the result was their concluding a Treaty in the year 1241, by which the two cities bound themselves to use their utmost efforts for the protection of trade by

Progress, sea and land. Brunswick, the chief inland town in the North-West of Germany, and connected in trade with both Hamburgh and Lubeck, was not long in acceding to the Treaty, and, in 1252, Deputies from each of the three met at Lubeck, where, among other arrangements of importance, they took steps for establishing factories in London and Bruges, as well as in a very different quarter, Novogorod in Russia. They assumed the name of *Hanse*, from an old German word signifying a Union or Association, and being, of course, open to new members, they were joined in the course of the next century by a number of cities and towns, such as Amsterdam and other seaports in the Netherlands; Dantzic, as well for itself as for the lesser towns in the North of Poland; and Cologne for the different trading places on the Rhine. In the XVth and XVIth Centuries, when the Confederacy may be said to have attained its highest point, the League comprised no less than sixty-four commercial towns, and was capable of asserting its rights by arms, by carrying on naval operations on a large scale. Their power was repeatedly felt by their neighbours. Thus the passage of the Sound by merchantmen being under the control of the Danish Government, which tried more than once to impose an arbitrary toll or tribute on the passage, the Hanse Towns equipped a fleet on each occasion, and obliged the Danes to desist from their claims. Commerce.

Such were the motives for forming and maintaining this Confederacy; we come now to the causes of its dissolution. As Civilization diffused itself in and Decline. the North of Europe, and the different Governments made a point of protecting trade, as well by sea as in their respective territories, less exertion was required on the part of the Hanse Towns. It became evident also from the example of Holland, that trade prospered most when each seaport, or each mercantile district, was left to manage its own concerns. Hence a gradual relaxation in the bonds of the Confederacy; so that during the last two centuries the name of Hanse Towns has been confined to Hamburgh, Bremen, and Lubeck.

These towns have still mercantile Consuls in London and elsewhere, but they are occupied with the concerns of their constituents only; not with those of the former members of the League.

Of the trading towns in the North of Europe, the Bruges. most remarkable in that early period (the XIIIth and XIVth Centuries) was Bruges. In those days of imperfect Navigation, to make a voyage from the Mediterranean to the Baltic and to return before the end of Summer, exceeded the ability of the mariner; hence the advantage of an intermediate station in which vessels arriving from the South might at once land and deposit their silks, wine, and other commodities, taking on board, in return, a cargo of the more bulky but equally useful products of the North. Bruges was fixed on by the Hanse Towns for this purpose: its situation was central; the adjoining country was well cultivated and peopled; while the town, nearly twelve miles distant from the sea, was beyond the reach of piratical incursion. Bruges had no navigable river, but it was the point of junction of several canals, and the one leading to the sea was of ample breadth and depth. The extent of ground occupied by the town was great, but the population, perhaps, at no time much exceeded the present number, forty thousand, for, in consequence of unfortunate differences between the citizens and the Government of the Netherlands, much of the foreign trade of Bruges was transferred to Antwerp towards the close of the XVth Century, the time at which it was about to become greater than ever, because the mercantile intercourse of the North of Europe began then to acquire a great extension.

The large vessels which were now coming into use, Antwerp. and which required considerable depth of water, gave an additional value to so fine a port as Antwerp. The Scheldt is there much broader and deeper than the Thames at London, and there are ample means of inland communication both by that and other rivers. The XVIth Century was the time at which these advantages were turned most effectually to account. English merchants fixed their staple at Antwerp instead of Bruges; vessels repaired thither from the South as from the North of Europe; the city walls were successively enlarged so as to contain the increasing population; and the trade of London being then only in an incipient state, Antwerp was, as regarded foreign intercourse, the most busy seaport in the North of Europe. Unfortunately her fair prospects were marred by political dissensions; by the arbitrary conduct of the Spanish Government under Philip II., and by the war that ensued, leading in 1585 to the memorable siege and capture of the city. Many of the merchants then removed to Amsterdam,

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and directed thither their consignments of goods. And in the following century, when the war was suspended, and all was tranquil in the Netherlands, the Dutch having the command of both sides of the Scheldt, effectually prevented the revival of the trade of Antwerp.

Hamburgh.

Hamburgh, more fortunate than either of the above towns, has in general escaped an interruption of its trade. It was founded at an early date, and was originally little more than a fortress; but the advantage of its position brought it trade and population, as the Civilization of the neighbouring Countries advanced. Subject for a time to the Counts of Holstein, it gradually obtained an extension of its privileges, became virtually independent, and continued so after that Province was incorporated with the Kingdom of Denmark. In the extent of its water communication Hamburgh may be compared to a Dutch seaport. An arm of the Elbe forms there two harbours, one on the East for boats, another on the West for ships. Another river, the Alster, forms beside the town a large basin resembling a lake, and within the town another of less extent, which serves as a harbour. Though Hamburgh is nearly eighty miles distant from the sea, the communication is easy on account of the great breadth of the Elbe. The same cause facilitates the access from Hamburgh to the interior of Germany for several hundred miles. The effect of these various advantages was to render Hamburgh in the Middle Ages a port of considerable consequence, though by no means to be compared to what it afterwards became. Vessels from the South of Europe proceeded to Hamburgh as soon as the improvement of Navigation made it unnecessary for them to shorten their voyage, by stopping at Bruges, as did ships from the Baltic, after the route by the Sound was generally adopted for the export of Baltic produce. Lubeck remained, like Bruges, comparatively stationary, after the XVth Century; because the chief utility of both was as intermediate ports, and the increased dexterity of mariners after that time enabled even distant seaports to open a direct intercourse with each other.

The Netherlands

No part of Europe has a stronger claim on the attention of mercantile men than the Netherlands, in particular the maritime Provinces of Flanders, Holland, and Zealand. In tracing the progress of Civilization, we have seen that the early improvement of Greece, that wonder of ancient times, was owing, in a great measure, to intercourse with more advanced Countries, and to the introduction of the useful Arts from Phœnicia and Egypt. The revival of trade, manufactures, and general improvement in modern Italy, the next great feature in Statistical History, is to be ascribed to various causes; to the continued intercourse of Italy with Constantinople and the remaining portions of the Greek Empire; to the natural fertility and consequent population of Lombardy; to the degree of Civilization preserved throughout the Dark Ages, in a Country so long the centre of the Roman power, and so superior both in number of inhabitants and general cultivation to France and Spain, which were merely Provinces of the Empire. But the Netherlands had none of these advantages: they had at no time been the seat of empire; their Government was not better than that of the other Northern nations; and surrounded by Countries which, in the Middle Ages, were very imperfectly cultivated and thinly peopled, they could derive no instruction from their neighbours. Yet the Netherlands took as remarkable a lead in national improvement, when compared with the adjacent Countries, with England, Denmark, France, and Germany, as did Italy when compared with the rest of the South of Europe. The origin of this superiority is to be sought in Physical causes; first, in the ease with which a level surface and an alluvial soil may be cultivated: and next in the means of transporting bulky goods along canals, or such great rivers as the Scheldt, the Maese, and the Rhine.

Their early cultivation.

First as to cultivation. Of the ease with which a level surface and an alluvial soil may be cultivated, we have a variety of examples, both in ancient and modern History. It is thus that we can account for the productiveness of Egypt, of the part of the Venetian territory adjacent to the mouths of the Po and the Adige, as well as of many level tracts in very distant parts of the World, as in Bengal along the banks of the Ganges, in Guiana on those of the Essequebo, the Demerary, or the Surinam. Without quitting our own Country, we may find many examples of easy cultivation and abundant produce in the fens of Cambridgeshire and Lincolnshire, which have been reclaimed by drainage during the present Age. Flanders being a Country of similar description, we need go no further to account for its early fertility and the density of its population; the latter was remarkable, first in the open country and in villages, afterwards in towns, at the head of which were Bruges, Ghent, and Antwerp.

Their navigable rivers and canals.

The next advantage of Flanders and Holland was the ease with which all bulky commodities, such as corn, wood, coals, and turf, could be conveyed from one part to another. In most Countries of Europe there are considerable distances between the mouths of great rivers: the Humber is remote from the Thames; the Elbe from the Weser; the Charente from the Garonne. But in the Netherlands these great inlets are both numerous and comparatively near to each other; they consist of the different embouchures of the Scheldt, the Maese, and the Rhine, each opening into a distinct part of the Country. Next, as to canals. In a soil both level and devoid of rocky substances, it was easy to excavate canals, and the consequence was, that the advantage of such communications was enjoyed in the Netherlands so long as four or five centuries ago, a time at which canals were unknown in almost every part of Europe, except Lombardy, and when neither France, England, nor Germany could boast of carriage roads. In those Countries commodities could be conveyed in no other manner than on the backs of mules and horses; and each district was, in a degree, confined to its local resources, at a time at which Flanders and Holland had easy means of transporting the most bulky articles.

Of these Provinces, the lead in agriculture was taken by Flanders, the soil of Holland being in those times, as at present, too damp for tillage, and being, in consequence, laid out chiefly in pasture. Manufactures were established at an early date in the towns of both Provinces, particularly in those of Flanders. But in Navigation a decided priority belonged to Holland and Zealand, admirably adapted as both Provinces are for ready access to the sea. Hence extensive fisheries, first on their own coasts, afterwards at a distance in the North Sea; hence also a coasting-trade extending, even in an early Age, to Hamburgh in the North and to Picardy

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and Normandy in the West. As the seamen gradually became more skilful, their voyages were prolonged on the one hand to the Baltic, on the other to Portugal and the Mediterranean. The Dutch thus became in the course of time the naval carriers of the North of Europe; other nations abstaining in a great measure from that which, with their deficient means and ignorance of seamanship, would have been a hazardous and even perilous employment. It is a curious fact, that two centuries ago, Wentworth, Earl of Strafford, when appointed Lord Lieutenant of Ireland, and anxious to proceed from Wales to Dublin, was obliged to wait until a ship of war from the Thames came round to convey him and his suite across the Irish Channel. There were in those days no Government packets, and no English merchant-ships suitable for such a purpose; the trade between England and Ireland being carried on almost wholly in Dutch vessels.

Chief Ports.

The chief seaports in the Netherlands in those times, as at present, were Amsterdam, situated near a great inland water called the Zuyder Zee; Dordt and Rotterdam, situated near the mouths of the Rhine and Maese; Antwerp, Middelburgh, Flushing, on the banks of or near the mouth of the Scheldt. Ghent is an inland town, and like Bruges, did not adjoin any great river or maritime inlet, but it communicated with the sea by a wide canal. Dordt is considered one of the most ancient seaports in Holland, and has been noted during many centuries for its trade in timber, sent down the Rhine in floats, and applied in Holland to a variety of purposes, to the building of ships and boats, as well as to the work of carpenters, joiners, and other mechanics. The timber of the growth of Holland is not large; hence it receives vast importations from Norway and the Baltic, as well as from the forests adjoining the Rhine. Rotterdam owed its increase to the facilities for intercourse afforded by the Maese, the Leck, and the maritime inlets to the South; but it was greatly surpassed by Amsterdam, which became to the North of Europe what Carthage in one Age, and Venice in another, had been to the Countries of the Mediterranean.

Rise of Amsterdam.

Without adjoining any great river, Amsterdam had access to the Rhine by a canal, and by the Zuyder Zee, to almost every part of the Country bordered by that extensive water. In early Ages, when vessels were small, and seamen were averse from long voyages, a ready access to an inland sea was of importance, and rendered Amsterdam the most commodious port in Holland for shipping from the Ems, the Wéser, and the Elbe, as well as from the coast of Jutland. The disadvantage of shallow water in the approach to the harbour of Amsterdam, is felt only by large vessels: it was of little importance in an Age when merchandise was conveyed in vessels or rather barks of light draught. Hence the early and progressive increase of this city, notwithstanding its occasional insalubrity, and the great expense of building on ground where, from the insecurity of the foundation, the houses must be erected on piles. Amsterdam was a place of importance so early as the XIIIth Century, having been one of the first seaports to join Lubeck and Hamburgh as a Hanse Town; it continued to increase during the XIVth, XVth, and XVIth Centuries, and had become the most eligible place of settlement for the merchants of Antwerp, when the capture of that city in 1585, and the oppressive conduct of the Spanish Government, led so many Flemings to forsake their homes. The following century (the XVIIth) was the prosperous era of Dutch trade, and a very great proportion of it, whether with the Baltic, the Mediterranean, or the East Indies, centered in Amsterdam.

It does not appear that the early prosperity of the Netherlands was owing to their form of Government or Civil institutions. Flanders, Holland, and East Friesland were for many Ages governed by Counts or Earls, having, like other nations of German origin, a kind of Parliament under the name of States. These three Provinces had during the Middle Ages little political connection, and were occasionally in hostility with each other. In the XVth Century, however, an end was put to such collisions, each Province becoming, by the intermarriage of the ruling families, subject to the House of Burgundy. Maximilian of Austria having married the heiress of that House, acquired her rich possessions, which afterwards passed to the Emperor Charles V. That Prince, born in the Netherlands, had naturally a predilection for his Country, and passed various edicts to advance Commerce and consolidate the union of the Provinces. He did not, however, discover much respect for their political privileges, or much solicitude to lighten the burdens brought on them by his incessant wars. A similar conduct, pursued with less judgment by his gloomy and bigoted son, Philip II., produced the separation of the Dutch Provinces, and a contest between them and Spain during more than half a century.

Hired troops and military supplies in the Middle Ages. Italians.

Before concluding our notice of the Middle Ages, it seems fit to explain in what manner the inhabitants of places so pacific in their policy as the Commercial towns of Italy, became connected with warlike Sovereigns, and rendered themselves auxiliary to their enterprise. We read in History, particularly at the battle of Cressy in 1346, of Genoese archers, by whom we are to understand not natives of Genoa, or troops in the service of the Republic, but military mercenaries levied in the adjoining Country, in consequence of a compact or Treaty with the French or other foreign Governments. Kings had in those days no standing armies, and to form disciplined troops from among the peasantry of their dominions was a tedious and difficult task: but in a city containing such a number of artisans as Genoa, arms were readily supplied, and combatants soon came forward where there were capitalists able and willing to contract for their services. Italy was in fact remarkable in the Middle Ages for her bands of *Condottieri*, or hired troops. A similar explanation is applicable to the Flemings or Walloons, so often mentioned among military levies in the Middle Ages. Flanders, without being more warlike than the neighbouring Countries, was the only part in the North of Europe which at that time had either a brisk traffic or a dense population. It had accordingly the means of supplying not only arms, but men far more dexterous in their use than the rustic followers of a Feudal master, whose time of service seldom exceeded forty days; for there was hardly a battalion of soldiers on permanent duty in any Kingdom in Europe before the year 1500.

Flemings.

Swiss.

The Swiss formed the third class of hired combatants in the times of which we speak, but their services were given under circumstances very different from the Italians and Flemings. Their mountainous territory could boast of neither Commerce nor large towns; their population was spread over the open country, and, in consequence of their poverty, discharged the obligation, which every citizen owed to the State, not by paying

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taxes, but by performing militia service. Hence there were in Swisserland many more men trained to arms than were required for the national defence; and hence also arose a readiness in the Governments of the different Cantons to transfer to foreign Governments the services of their Countrymen on certain terms, which it was usual to embody in a Treaty, or, as it was technically styled, a capitulation.

Overland traffic from Italy to Germany.

It remains that we give an example of the rude mode of conveying merchandise by land in the XIIIth and XIVth Centuries. The trade of Venice with the Levant became considerable about the time at which Augsburg, Ulm, Nuremberg, and other towns in the interior of Germany were increasing their population and traffic. The result was a considerable intercourse between Italy and Germany by land, which was carried on across the Alps, chiefly by Trent and Inspruck, through a Country too mountainous and rugged for carriage-roads, and in which, consequently, the merchandise was conveyed on the backs of mules and horses. This mode of transport was expensive, even in those days of low wages and cheap provisions, because the weight borne by these animals on their backs, being hardly a fifth part of that which they can draw on a carriage-road, many hundreds of them were required to convey the cargo of a small vessel. It is a similar want of carriage-roads which at present narrows the intercourse with Mexico and other parts of Spanish America. Mules and horses are cheap in Countries possessing extensive pastures, but their power of carrying being limited to three or four hundred weight for each animal, the expense can be borne only by articles of value, such as cottons, fine woollens, or cutlery. The cost of conveyance being thus high at the time of which we are now speaking, the traffic across the Alps was confined to valuable merchandise, such as the silks, the cottons, and the spices of India, or the jewellery of Venice. Heavy articles, such as oil and wine, were conveyed by shipping from Italy to Bruges.

The want of carriage-roads was general throughout Europe in the Middle Ages; almost all inland traffic was carried on in the manner we have mentioned by beasts of burden, proceeding along tracts which hardly deserved the name of roads, being little else than bridle-paths. The non-existence of an effective Police, and the means of concealment and escape afforded to robbers by the extent of forests, marshes, and uncultivated land, made it necessary for mercantile dealers to afford protection to each other, and to travel in parties or companies, in the manner of an Eastern Caravan. To this must be added, the difficulty in holding a mercantile correspondence, for it is not more than two centuries since the Governments of even the most improved part of Europe began their Post-office establishments. If besides these various disadvantages we consider the inefficiency of machinery, we shall find reason greatly to modify the popular notion of the general cheapness of commodities in the Middle Ages. Wages were low; and country produce, such as corn, wool, and cattle, were to be had for little money; but the finer manufactures, or whatever required a combination of capital and skill, were in reality dearer than at present: they cost, it is true, a very small sum when purchased with silver, but a great deal when exchanged for labour or raw produce.

Such was the state of productive industry in Europe during the Middle Ages; rude, backward, and inefficient in every Country except Italy and the Netherlands. But we are now about to enter on a brighter era; on the discoveries and improvements which, slowly as they operated, had, in the course of two centuries, the effect of producing a great extension of navigation: the result of which was the discovery of America, and an import from that part of the World of the precious metals, attended with a remarkable effect on the Commerce and state of Society in Europe.

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Improvements in Navigation.

Discovery of the Mariner's compass.

The discovery of the Mariner's compass, or of the property of the magnetic needle, which makes it point steadily to the North, was made about the year 1302, by an inhabitant of Amalfi, a seaport in the Kingdom of Naples. This discovery relieved seafaring men from the necessity of guiding their course by uncertain marks, such as the aspect of headlands by day, or the often interrupted view of the stars by night. The use of the compass, consequently, became general, and tended materially to facilitate voyages in the established lines of mercantile intercourse, but it was long before it extended the range of Navigation. So backward were the merchants and mariners of that Age, and so slightly were they animated by the spirit of enterprise, that half a century elapsed after this discovery, ere navigators ventured into unknown latitudes, and even then they advanced at a very tardy rate. The Mediterranean had long been explored, and the Atlantic had been sailed over to a high Northerly latitude; the region now to be visited was the Western coast of Africa, and the task of doing so fell to the Spaniards and Portuguese: not that either People could boast of much progress in seamanship, but because of all the nations of Europe, they were, in point of situation, nearest to the Country in question. The Venetians and Genoese, superior as navigators, were comparatively remote from Africa. Still more so were the Dutch and Flemings. Aided by the compass, the Spaniards now ventured to proceed to the Canary Islands, about two hundred leagues from their own shores, while in Portugal a regular plan of discovery was formed with the support of Government. As yet the Portuguese vessels had ventured no further South than Cape Non, on the coast of Morocco; their next effort, which in the present Age it would be ridiculous to call an effort, was to double that Cape, and to reach Cape Bojador, which was known to be about sixty leagues to the South. That being accomplished, two small vessels were some time after equipped for the purpose of doubling Cape Bojador, and proceeding further Southward: they were sailing slowly along the shore, according to the timid practice of the Age, when a squall of wind drove them out to sea, and led to the discovery of Madeira. That island, situated in the Ocean at a considerable distance from any coast, became the object of repeated voyages on the part of the Portuguese, and accustomed them by degrees to a bolder Navigation in the open sea. In the course of years they discovered the coast of Africa so far as the mouth of the Senegal and the Cape de Verd Islands, which being within fifteen degrees of the Line, was a sufficient distance to the South to prove that the Tropical regions were not, as had been vulgarly supposed, uninhabitable on account of heat. The further progress of the Portuguese, however, was very slow, there being a general impression that little Commercial advantage could be reaped from intercourse with Countries so

Progress of Portuguese navigation.

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remote, and situated in so hot a climate. At last, in the year 1484, a flotilla, fitted out for the purpose, persevered in navigating the coast of Africa, along the shores of Guinea and Congo, advancing no less than one thousand five hundred miles to the South of the Line. A few forts were then built on the coast of Guinea, and settlers were sent out to them from Portugal. The great inducement to persevere was the hope of reaching India by the South of Africa; a hope now strongly confirmed by the figure of the coast of Africa, which from the mouth of the Gambia recedes greatly in an Eastern direction, as if to point out a route to the Country so long and anxiously sought after. Another flotilla was now fitted out, which stretched boldly towards the South, four hundred leagues further than the preceding, but meeting with a succession of tempests, was obliged to return without doubling the Cape of Good Hope, which they saw, and to which, from the weather they had experienced, they at first gave the name of Cape of Tempests This took place in 1486: several years elapsed before fitting out another expedition: at last, in 1497, Vasco di Gama succeeded in sailing round this formidable promontory, and accomplished a voyage to India, five years after Columbus had effected the discovery of the West Indies and America.

Trade with India by the Cape of Good Hope.

In India, the Portuguese found a Country of considerable population and trade; less wealthy, indeed, than had been pictured in the imagination of ardent adventurers or credulous merchants, but sufficiently so to form a basis for extensive exports to Europe. Most of these were now directed to Lisbon, the voyage round the Cape of Good Hope, difficult as it was to the navigators of those days, being much less tedious and expensive than the route by the Red Sea, Alexandria, and Venice. But America was in a very different condition from India: it was uncultivated and almost unpeopled; containing no manufactures and little raw produce in a state for use, the consequence not of deficient fertility, but of the natives being incapable of preparing it for sale, or bringing it to the coast to be shipped. Ages elapsed before the influx of settlers from Europe, and the increase of the native population rendered the exports of merchandise from America, her coffee, sugar, cotton, cochineal, or indigo, of importance to the Commerce of Europe: the chief effect produced during the century following the discoveries of Columbus, arose from a different cause; from the increased supply of gold and silver. This subject is of great importance in a mercantile sense, and has a claim to be investigated with minute attention.

Supply of Gold and Silver from America.

The Countries occupied by the Spaniards during the thirty years following the discovery of the West Indies, were St. Domingo, Cuba, Porto Rico, and other islands in no way remarkable for the supply of the precious metals. At last, in 1521, they obtained possession of Mexico, and began to bring considerable supplies of silver into Europe. The amount of these was greatly increased after 1545, by the produce of the rich mines of Potosi in Peru. It is thus about three centuries since the import of silver from America began to be sensibly felt in Europe; and it seems fit, with a view to mark the extent of the supply at different periods, to divide that time into three equal periods. To begin with the century that elapsed

From 1530 to 1630.

From the year 1530 to 1630. At first about half a million sterling of silver appears to have been added to the currency of Europe from the mines of America annually; after which the quantity increased progressively, so as to form, towards the close of the period, an addition of about two millions annually; the whole forming an augmentation of metallic currency to the extent of about one hundred millions sterling in a hundred years, or an average of a million annually. This is, in substance, conformable to the estimate of Mr. Jacob, in his valuable publication, *On the Precious Metals*, vol. ii. p. 70. 131; after making a suitable deduction for the proportion of the produce of the mines conveyed to India or used in Europe for plate, ornaments, or manufactures. We now come to the second period; to the hundred years which intervened

1630 to 1730.

From 1630 to 1730. The produce of the American mines continued to increase largely during this century, but as the export of silver to India, and its use in plate, ornaments, and manufactured articles, was far greater than before, the remainder, forming the addition to the currency of Europe, ought not to be computed at more than a million and a half, or two millions annually.

1730 to 1830.

From 1730 to 1830. The course of circumstances continued for many years the same as before: the mines increased in produce, but the export to India was maintained, and the consumption of silver in plate, watches, gilding, received a great extension; so that the yearly addition to the metallic currency of Europe appears to have been on an average nearly as in the former century; *viz.* from a million and a half to two millions annually. If this addition was so nearly uniform, how are we to account for the remarkable fluctuation in prices which has taken place in the last forty years? we mean, their continued rise until 1814, and their continued fall since that date. The answer is, that these fluctuations had little connection with the state of the American mines; they were the consequence of the alternations of War and Peace throughout Europe; and, in England, of the emission and contraction of Bank paper.

Rise in the price of commodities.

It thus appears, that during the first hundred years after 1530, the yearly addition to the metallic currency of Europe from the American mines, averaged about a million sterling a year; and in the succeeding two centuries between a million and a half and two millions sterling a year. So large an increase of the circulating currency had necessarily a great effect on the prices of commodities in Europe; but the degree of that effect has in general been loosely stated and greatly exaggerated. Since it is of great importance to ascertain as correctly as possible the extent of the rise of prices at different epochs, we shall, as before, divide the time that has elapsed since 1530 into three equal periods; beginning with the century

From 1530 to 1630.

From 1530 to 1630. According to common tradition and belief, the rise in the price of commodities in the course of these hundred years was enormous; not less than in the proportion of five to one, five hundred pounds being required in 1630 to purchase the various articles which a century before might have been bought for one hundred. And that, too, not from alteration of the coin; for such is asserted to have been the advance in prices, after making allowance for the different degradations of the coin on the part of Government during the period in question. Such is said by contemporary writers to have been the rise of prices, not only in England, but in France, Spain, Italy, and as far as

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1562, when the home price was at	10*s.* per quarter.
1593	20*s.*
1604	26*s.* 8*d.*
1623	32*s.*
1656	40*s.*

This exhibits an advance in the remarkable proportion of four to one in the course of a century, but such evidence is to be received with great qualifications. The rise appears to have applied chiefly to our maritime districts, to the vicinity of seaports, where, on a rise of prices abroad, it was easy to buy up and effect an export of our corn. In the inland Counties there was, from the want of roads, a very limited intercourse in so bulky an article: each district supplied its own wants; corn was commonly paid for by barter or by labour; a mode of transacting which was little affected by the state of markets in the Capital and seaports. The abovementioned rise cannot, therefore, be considered to have been general either in England or on the Continent, three-fourths of which were at that time little influenced by maritime intercourse, but conducted their traffic on the primitive plan of barter. In those parts the price of corn varied much less.

Next in regard to the rate of payments for other purposes. The rise in the wages of labour during the XVIth Century, though very considerable, was by no means in proportion to the rise in the price of corn: the same distinction held in regard to manufactures, whether woollens, linen, hardware, or leather, the cost of which, in those times of deficient machinery, depended mainly on the rate of labour. These form very important deductions from the alleged rise in the proportion of five to one, and justify us in materially qualifying the assertions of an Age in which there were few Statistical returns and a considerable disposition to exaggerate. The point to be ascertained is the advance not merely in corn and other exportable produce, but in manufactures, house-rent, wages, and the other constituents of family expenditure taken collectively and computed together with the cost of provisions. Now, reckoning in this comprehensive manner, we consider that in the hundred years from 1530 to 1630, the rate of advance did not exceed two to one; that is, £200 in the latter year would have sufficed to effect the purchases or pay the services which, a century before, might have been obtained for £100.

We come now to the second century of the influx of silver from America, *viz.*

1630 to 1730. From 1630 to 1730. During this period there was also a rise of prices, but in an inferior degree. It took place chiefly in the wages of labour and in articles of which the cost depended principally on labour. Corn did not rise either in England or in France, but there occurred in most other branches of expenditure an advance which rendered the rate of housekeeping and a provision for a family more costly by nearly a fourth than in the preceding century; so that towards the end of the period, the average rate of prices may be considered as in the proportion of five to four compared with the rate at its beginning, £250 being required in 1730 to purchase the commodities which, in 1630, might have been procured for £200.

This brings down our calculation to the last of the three periods; to the century that intervened

1730 to 1830. From 1730 to 1830. During thirty years of this period prices were nearly stationary; after 1761 they rose progressively, but not rapidly; after 1795, and particularly after 1797, the era of the Bank restriction, they advanced in a ratio beyond all example; but after 1814 they fell with equal rapidity, so that the result of all these fluctuations is, that in the present year the price of a number of commodities taken collectively is greater than it was a hundred years ago by little more than a fifth, the cheapness of manufactures forming a counterpoise to the rise in corn and other raw produce.

The advance of prices in the XVIIIth Century appears thus to have been in nearly the same ratio as in the XVIIth.

Summary. The result of the preceding estimate is, that a given amount of labour, provisions, raw materials, and manufactures, which might have been purchased in England

about the year 1530	for £100 in money,
appear to have cost in 1630	200,
in 1730	250,
in 1830, or the present year	300.

It is very remarkable that the rise of prices in the first of these periods should have exceeded so much that of the second and third, although the supply of silver from the American mines continued to increase during the whole time. This is a very nice question, and a few remarks on it may tend to throw light on the state of trade and manufactures in Europe in the XVIth Century.

Rise of prices in the XVIth Century. The effect of War and of a large Government expenditure, as has been strongly proved in the present Age, is to cause a considerable rise of prices. This effect is produced in various ways: first by the direct addition to the cost of an article from the imposition of a tax on it; next by the increase in the rate of freight and other charges on intercourse; but far more than all by withdrawing men and capital from productive to unproductive employment; from Agriculture and Manufactures to military purposes. In the XVIth Century the belligerent Powers on the Continent were Spain, France, and Germany; the scenes of their operations were Italy and the Netherlands. The rise of prices having been as great in those Countries as in England, a part of that rise is, doubtless, to be attributed to War; for this was the time at which the principal Governments of Europe increased their armies; when our Henry VIII. and Francis I. of France indulged their chivalrous projects; and when the more deliberate ambition of Charles V. and Philip II. of Spain kept the fairest portion of Europe in continued agitation. All this led to an increase of public burdens, and to an advance in the price of commodities, but not in a degree commensurate with the rise in prices which actually took place. The century that followed was still more marked by expensive Wars and augmented burdens, being the time at which the aggressions of Louis XIV. roused all Europe against France, and when the military establishments of that Country, as well as of England and Holland, were doubled and tripled; yet the rise of prices was by no means so great as

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in the XVIth Century. The latter must, therefore, have been increased by peculiar circumstances, the chief of which doubtless was the limited field on which the supplies of silver from America for some time acted.

The field for the use of silver was limited in this manner: the population of Europe being in those days chiefly rural, and too poor to make use of silver, that metal was current only among the inhabitants of the Capitals, the seaports, and a certain number of inland towns. Now all these places were then far below their present scale both in numbers and property. The following Table may tend to bring the question to issue, by conveying a view of almost all the towns entitled to be considered as in any degree the seats of trade and manufactures in Europe, three centuries ago.

Chief Towns in Europe in the XVIIth Century.

Italy.

Rome.	Turin.
Naples.	Parma.
Venice.	Padua.
Genoa.	Verona.
Milan.	Brescia.
Florence.	Cremona.
Bologna.	Pavia.
Pisa.	Mantua.

Sicily.

Palermo.	Catania.
Messina.	

Belgium.

Antwerp.	Louvain.
Ghent.	Tournay.
Bruges.	Lisle.
Brussels.	

The Dutch Provinces.

Amsterdam.	Haarlem.
Rotterdam.	Utrecht.
Dordt.	Groningen.
Leyden.	Middelburg.

France.

Paris.	Rouen.
Marseilles.	Metz.
Lyons.	Troyes.
Nantes.	Avignon.
Bourdeaux.	

England.

London.	Coventry.
Bristol.	Plymouth.
York.	Newcastle.
Norwich.	

Germany.

Hamburgh.	Ratisbon.
Bremen.	Leipsic.
Lubeck.	Dresden.
Altona.	Nuremberg.
Brunswick.	Augsburg.
Cologne.	Munich.
Frankfort.	Wurzburg.
Aix la Chapelle.	Vienna.
Mentz.	Prague.
Strasburg.	Berlin.

Swisserland.

Basle.	Geneva.

Spain.

Seville.	Saragossa.
Cadiz.	Valencia.
Madrid.	Carthagena.
Granada.	Malaga.
Barcelona.	

Portugal.

Lisbon.	Oporto.

The Baltic and Norway.

Copenhagen.	Riga.
Stockholm.	Gottenburg.
Dantzic.	Bergen.
Konigsberg.	

Russia.

Moscow.	Kiow or Kief.
Novogorod.	

Poland.

Warsaw.	Cracow.
Wilna.	

Turkey.

Constantinople.	Adrianople.
Salonica.	

Poverty of agriculturists in the XVIth and XVIIth Centuries.

Such were in those days the principal cities and trading towns in Europe; the places to which the silver imported from America gradually found its way, and gave a stimulus to productive industry, to mechanics, manufacturers, navigators. Adjacent to most of these places was a considerable district cultivated in a manner less rude than the Country at large: the peasantry had there attained the rank of tenantry, and were enabled, by their intercourse with the towns, to pay their rents in money, while nine-tenths of their brethren scattered over the Provinces, were almost strangers to the use of silver, and could pay their rent no otherwise than in labour or produce.

What, it may be asked, was the collective amount of population in the various towns which we have enumerated and the neighbouring districts? It appears to have been in all between four and five millions; but to these are to be made two considerable additions: first the lesser towns, whether maritime or inland, in which there were half-yearly or yearly Fairs; and the much longer list of burghs or petty places in which there were weekly markets, and which, poor and thinly peopled as they were, have a claim to consideration in our estimate, because silver was, to a certain extent, their circulating medium. Adding the population of all these places and their surrounding districts to that of the Capitals and larger towns, we may consider the result as exhibiting the total of the European community among which silver at that time circulated. The number seems in the earlier half of the XVIth Century to have been below ten millions; while in the latter half of that period it may have amounted to between twelve and fifteen millions, among whom, and not a greater number, the silver from America appears to have been distributed.

Though the numbers we have thus assigned to the

Commerce. various towns of Europe and their adjacent districts are not a fourth of their present population, they will be found large when allowance is made for the total difference of the times. In the XVIth Century country work was so rudely managed, the ploughs, the tools, and implements of husbandry, from scarcity of iron, were so defective, that in every part of Europe so many as eighty persons in a hundred were necessarily resident in the country, the labour of thatl great proportion being indispensable to raise subsistence for the community at large. There were then, as we have shown, very few roads; and consequently few draught-carriages, for corn, wool, and other produce were conveyed on beasts of burden. Now such conveyance, being both difficult and expensive, was considerable only in the neighbourhood of towns: in country parts, that is, throughout nine-tenths of Europe, each hamlet or district was obliged to supply its wants from its local resources, scanty as they were: traffic was carried on by barter, and the only metallic currency was copper. All this shows that we must beware of judging in any degree of our farmers and peasantry of former times by those of the present Age. A better criterion will be found among the peasantry in the East of Europe, in Poland, Hungary, Russia. There, even at present, the privations are great; the mode of living extremely rude: silver is so little used in paying either wages or rents, that most of the labourers are without the means of buying woollens or manufactures of any kind; they are obliged to protect themselves from the cold of winter by a covering of sheep or lamb-skins.*

Improved Condition of Agriculturists.

Such in the XVIth Century was the state of the peasantry throughout Europe with the exception of certain districts in Lombardy or the Netherlands; or in the vicinity of such Capitals as London and Paris. Money-rents were very rare; they arose in process of time out of the improvements which productive industry received from various causes, above all from the increase of town population and the augmented supply of silver from America. This may be best explained by a reference to the present Age, in which we have had a very striking example of the invigorating effect of a continued rise of prices on farmers, merchants, and the productive classes generally. After 1797, that is, after our Banks were exempted from paying their notes in cash, money became abundant, and the check on the expenditure of Government was removed. Provisions, arms, clothing, shipping, were required on a scale of unprecedented amount, and all were furnished without difficulty, because the steadily continued supply of money gave a general stimulus to the productive classes. Our growth of corn being insufficient for our consumption, prices rose year after year and the circumstances of farmers improved, particularly in such parts of the Kingdom as Norfolk, Northumberland, Scotland, in which long leases are customary. Hence an increase of capital among the better class of tenants, and a beginning of capital among those who till then hardly knew what capital was. Similar to this was the course of circumstances among the tenantry of England, during the long reigns of Henry VIII., Elizabeth, and James I.: prices were in general on the rise, and our agriculturists experienced a progressive improvement of their circumstances. This improvement proceeded, it is true, very slowly compared to that of our farmers during the memorable twenty years from 1794 to 1814; but in one very material point our ancestors had the advantage; they suffered no reaction; the capital they acquired was preserved and handed down unimpaired to their sons and grandsons, prices continuing to rise during more than a century, and afterwards maintaining the advance that had taken place. For silver continued to come in, and the population of our towns, in other words the number of the consumers of country produce, was regularly on the increase.

The effect of an improvement in circumstances so long and so happily maintained, was to change the more active part of our peasantry into yeomanry; into tenants able and willing to pay their rents by money instead of by the primitive mode of labour and produce. This change, beginning with the districts adjoining the Capital and the larger towns, extended itself gradually over the more distant Counties during the XVIth and XVIIth centuries, adding largely to the national wealth, and extending the field for the circulation of silver. Holinshed, adverting in his *Chronicles* to the scanty portion of silver circulating among our farmers about the year 1500, "says, "If one of them did cast down his purse, and therein six shillings in silver, it was very likely that all the others present could not lay down so much against it." Now it is no exaggeration to assume, that in the hundred and fifty years which followed the date of this anecdote, the proportion of English farmers who paid their rents in money, and who in their buying and selling transactions made use of gold and silver, increased tenfold. A similar, though by no means an equal improvement of circumstances took place among the agriculturists in various districts of the Continent; in the vicinity of Capitals, seaports, and the larger inland towns. On the Continent there was also a regular increase in the number of the consumers of country produce, distinct from agriculturists; in mechanics, manufacturers, the professional classes, and other inhabitants of towns. In Holland this increase was rapid during the XVIIth Century; in France, Germany, Spain, and the vicinity of the Baltic, it was slow, but in steady progress. The labour of husbandmen became more efficient; their tools and implements were improved; a given number were able to raise a greater quantity of corn and other produce. The result of the whole was a surprising increase in the number of persons, whether in town or country, among whom gold and silver circulated; so that a yearly supply from America of two millions sterling was far less felt in Europe in the XVIIth and XVIIIth Centuries, than one million had been in the XVIth.

Mercantile intercourse of Europe and America.

Having now explained the rise of prices, it remains to add a few remarks on the mercantile intercourse of Europe with America in the XVIth and XVIIth Centuries. This was long on a small scale, because the thinness of the population in America restricted both the supply of produce from that Country and the demand for manufactures from Europe. The mode of conducting the trade was this. The silver sent from America to Spain was for account partly of the Spanish Government, but more for that of Spanish merchants connected with Mexico and Peru. It was landed at Seville or Cadiz,

* See a valuable book lately published *On the Rent of Land and Distribution of Wealth*, by the Rev. Richard Jones. See also Mr. Macculloch's *Commercial Dictionary*, head of *Fur Trade*.

Commerce. whence the portion belonging to Government was forwarded to the Treasury at Madrid, while the sums remitted for account of individuals were delivered to the merchants. On the part of the Government, these periodical supplies were distributed and expended in the purchase of arms, clothing, the pay and subsistence of troops: on the part of the merchants, in the purchase of quicksilver for extracting the silver from the ore at the mines, of clothing and tools for the mining workmen, of machinery, and of various manufactures required in Mexico and Peru, Countries in which the Art of manufacturing was almost wholly unknown. Italy and the Netherlands were the only Countries which had manufacturing towns of importance: other parts of Europe participated in the trade directly, sending to these a supply of raw materials. England, at that time too little advanced in the weaving of woollens to send abroad cloth, felt the benefit of the American trade in an augmented export of wool to the Netherlands; in the same manner as the iron mines in the North of Italy increased their supply of that material to Milan and Brescia, which were noted for their manufactures of hardware.

The Trade of Holland.

Extension in the XVIIth Century.

From the influx of silver from America, the prominent feature in our sketch of the XVIth Century, we turn to that which most strongly marked the XVIIth, the extension of the trade of Holland. No subject is more interesting and instructive than the Commercial prosperity of a Country, so limited in its extent and apparently so little favoured by Nature: in no part of the World shall we find a more striking example of the triumph of assiduity and perseverance over Physical obstacles. And first as to the causes of this prosperity. The progress of productive industry in Holland appears to have been as follows. The vicinity of so much water, as well along the coast as in the great maritime inlets, led to extensive fishing on the part of the inhabitants, first for their own supply, and next for sale to their neighbours. At the same time, the repair of the dikes and other works required to preserve so low lying a Country from the irruption of the rivers and high tides, produced habits of regular labour; while, in the third place, the practice of navigating the great rivers and the adjacent coasts, gave the Dutch a knowledge of seamanship rare in the Middle Ages in any part of Europe, except Italy. The Dutch were thus enabled to become the naval carriers, first of the North, afterwards of the South of Europe, not only conveying to a distance the products of different Countries, such as the corn, the flax, the timber of the Baltic, the wool of England, the wines of France, the oil and fruits of Spain and Portugal; but engrossing the coasting trade of most of those Kingdoms. Such was the situation of the Dutch about the year 1570, when the intolerance of Philip II. of Spain led to those Civil troubles which ended in Holland and the adjacent Provinces withdrawing from his yoke, and forming themselves into a separate State, under the name of the Seven United Provinces. From that time forward the Dutch added to their Physical advantages the still greater blessing of good Government. Having suffered greatly from Religious Persecution, and seen how much the public welfare is injured by it, they opened their Country to oppressed foreigners; and no solicitation of foreign Powers could ever prevail on them to withdraw their protection from such refugees. Toleration in Religion was accordingly complete in Holland, at a time when in other Countries it was enjoyed very imperfectly, or not at all: while in regard to the administration of justice, a strict impartiality was observed between natives and foreigners. Hence the influx into Holland of a number of valuable settlers, first from Belgium and France during the persecutions for Religion; afterwards from Germany during the Thirty Years' War; and, in some degree, from England in the Civil troubles under Charles I.

So early as the XIIIth Century Amsterdam and other Dutch seaports were of sufficient importance to be members of the Hanseatic body. Towards the year 1500 the shipping of Holland had so increased that three or four hundred sail were regularly employed in the Baltic trade, performing commonly two voyages a year each. An equal number appears to have been engaged in intercourse with France, England, and Spain. Before the year 1600 the shipping of Holland was further increased, and still more in the course of the XVIIth Century. John de Witt, who guided the affairs of his Country so long and so ably, stated in his printed Works, that in the twenty-seven years which intervened between the Peace with Spain in 1613 and the time at which he wrote, *viz.* 1670, the trade and navigation of Holland had increased one half. This period was followed by long and expensive Wars with France, involving a heavy addition to the taxation of the United Provinces, and augmenting the wages of labour in a very injurious degree. Still their institutions were so good, the advantages of the ample capital and tried industry of the inhabitants were so substantial, that their Commerce continued long to stand its ground. In the year 1700 the mercantile navy of England amounted by an official return to 261,000 tons; the seamen to 27,000. Of those of the Dutch we have no regular account, but it is probable that their numbers were fully double those of England, both in seamen and tonnage.

Causes of its prosperity.

The Government of Holland never listened to the false doctrine of endeavouring to raise or manufacture at home articles which they could obtain at a moderate price from abroad. The poverty of their soil was in some measure the cause of this judicious policy and of their extended navigation. They considered it no disadvantage to part with money to buy corn in Germany or in the Countries of the Baltic; nor did they ever stimulate a home manufacture by bountres. The trade in corn was always free, and in consequence, so long as two centuries ago, Holland was considered a depot for the occasional supply not only of England, France, and other neighbouring Countries, but of Portugal and Spain; for the warehouses of Amsterdam, according to Sir Walter Raleigh, generally contained seven hundred thousand quarters of corn, none of it of the growth of the Dutch Provinces.

If we analyze the causes of the Commercial prosperity of England, we shall find them to be partly Physical, partly Political. Among the former are our length of coast, our easy communication by water, the abundance of our coal and iron mines, and the vicinity of these mines to navigable rivers. Of our Political advantages, the chief have been the early introduction of the Reformed Religion, the check of the legislative on the executive branch of Government, and during several centuries a succession of Princes exempt, in a great measure, from a mania for War. Holland could boast neither of mines nor of a fertile soil: but in communica-

Commerce. tion by water her advantages were still greater than those of England. She early enjoyed the blessing of the Reformation, and possessed in her States or deliberative Assembly, a direct though not always an effectual check on the executive branch of Government.

Decline. Such were the causes of the extension of the trade of Holland. We come now to the reverse of the picture—to its decline. That dated from the early part of the XVIIIth Century, and had made considerable progress before 1750. Of this distressing change the

The Causes. cause was neither deviation from sound policy on the part of Government, nor relaxed industry on that of the people, but the pressure of heavy taxation, and the insufficiency of the resources of the Country to meet its burdens; first the sums required yearly for its defence against the sea, and next the much greater payments for the interest of the debt incurred in its long-continued wars. In that respect the lot of Holland had been particularly severe. She was oppressed in the first instance by Spain, assailed in the next place by England under Cromwell and Charles II., and finally obliged to resist the unprincipled ambition of Louis XIV. during three successive Wars; efforts by far too great for so small a State.

Further causes of the decrease of Dutch navigation may be found in the improvement of other Countries, and in the measures of their respective Governments for appropriating to their own subjects first their coasting trade, and afterwards their general import and export business. Ship-building and seamanship, Arts little understood in the North of Europe during the XVth and XVIth Centuries, had now become familiar to the inhabitants of the maritime districts of England, France, Denmark, and the North of Germany. In all those Countries the Governments took steps to carry on their foreign trade by direct voyages, and to avoid the circuit of the Netherlands. Entrepots were no longer necessary when a knowledge of navigation had become general, and the quantities of produce to be conveyed were so great as to make it expedient to fetch them from the Countries of their growth.

But the trade of Holland, though reduced as regarded Europe, was still very considerable to India and the West Indies until the latter part of the XVIIIth Century, when the contests with England, partly after 1780, during our first American War, but much more after the occupation of Holland by the French in 1795, led to the most unfortunate results: to the loss of the Dutch colonies, the continued suspension of their navigation, and a great depression of their funded property. To these were added, after 1810, the anti-commercial edicts of Bonaparte, so that in the latter years of the war the Country was plunged into the greatest distress.

The return of general Peace in 1815, and the prospect of its long continuance, revived the courage of the Dutch, and led them to resume, in some degree, their Commercial activity. Without flattering themselves with a return of their former prosperity, they have good grounds to hope for a fair share of the trade of Europe. The Rhine and the Maese are now more important than ever as inlets into the neighbouring Countries, the difficulty of ascending them being greatly lessened by steam navigation; while in the maritime Provinces, the continued level of the soil is very favourable to the conveyance of bulky goods by land as well as by water. Great improvements have of late been made in the public roads, and that which in England is now sought at so heavy a charge, a smooth surface, is found in Holland almost without expense. Add to this, that the scientific discoveries of the Age promise to be beneficial to Holland, by lessening the heavy expense attendant on her peculiar position. The strength of her dikes may be increased by planting roots which in other Countries are found to give tenacity to a sandy soil; while the surprising improvements lately made in England in raising water by steam engines, cannot fail to be of service in a Country so liable to suffer from water overflowing and remaining stagnant on the surface.

Commerce of England

Historical sketch of English trade from A.D. 1000 to A.D. 1600. England was considerably later than Holland or Flanders in arriving at Commercial eminence. Under William the Conqueror, the Public revenue appears to have been between £100,000 and £200,000 a year, arising less from taxes than from the Royal demesnes. The population of England, which at the time of the Conquest hardly exceeded a million, increased in the course of the succeeding three centuries to somewhat more than two millions, such being the amount according to the census taken by order of Government in 1377, the last year of the reign of Edward III. The people were scattered in cottages and hamlets over the open country, or rather over those portions of it that were cultivated, for in those days marshes, forests, and heaths covered a very large extent of our territory. The villages, for they were too insignificant to be called towns, increased their population very slowly. The pastures both for sheep and large cattle were extensive: the chief export from the Kingdom was wool, and the amount sent abroad varied from £100,000 to £250,000 a year. This export took place chiefly to Flanders, and, in a small degree, to France, Spain, and Italy. London was the chief shipping port, and the English of those days being unacquainted with the Continental Languages, our foreign trade was conducted chiefly by foreigners residing in London; *viz.* Flemings, Italians, and Frenchmen. Business in bullion and coin was long carried on by Jews, but after their expulsion, in the reign of Edward I., that important branch was taken up by Italians from Venice, Pisa, and Genoa, who were all called Lombards, and who gave their name to the street so well known as the chief resort of our Bankers.

Most part of the foreign trade of England in the Middle Ages was conducted by Companies: individual capitals were scanty, and a joint stock was indispensable to repair any considerable losses arising from shipwreck or failures. The vessels employed in our foreign

Our navigation. trade were chiefly Dutch and Italian: those in the coasting trade were English, but they were few in number; for our towns were then too small to need any great supplies of timber, coal, or other articles generally brought by water. The coal-works at Newcastle now so interesting a part of our mineral treasures were wrought on a very small scale till after the year 1300, for the fuel in common use throughout England was wood, a great part of the country being covered with forests. Coals, when first brought to London, were used (as they are at present in France) only by smiths, distillers, soap-boilers, and other manufacturers; not in dwelling-houses, the smoke being considered injurious to the health of a family. That prejudice continued during several centuries; but when it was at last removed, the superiority of coal as fuel, joined to the

scarcity and high price of wood, rendered its use quite general in London, and greatly increased the shipping employed in our coasting trade.

The fisheries were carried on at an early date in the Channel, as well as on the Eastern coast, and contributed to the extension of several of our seaports, such as Plymouth, Yarmouth, Colchester, Lynn.

Effect of war on our trade.

The wars with France, waged by our Edwards and Henrys, were very injurious to our productive industry, but Civil wars are far more so than foreign contests, whatever may be the expense of the latter. In this manner the long struggles between the Houses of York and Lancaster in the XVth Century greatly checked the progress of our population, agriculture, and manufactures; keeping the nation in a great measure from reaping advantage from our extent of coast, our navigable rivers, and our mines of coal and iron. Happily, those times of strife and bloodshed were succeeded by a very long period (more than a century and a half) of domestic quiet. This repose, together with the benefit arising from the early introduction of the Reformation, and a course of government, which, though very different at different times, was, in the main, judicious, enabled the Country to recover from its misfortunes, and to establish its agriculture and trade on a solid basis.

The XVIth Century.

The reign of Henry VII. afforded almost the first example of useful laws enacted in regard to the national industry. Until then, the power of purchasing land had been confined in England, as it is at present in Hungary and other half-civilized Countries, to men of a certain rank; but a double blow was now struck at Feudal usages, for while by one Act of Parliament landholders were enabled freely to dispose of their estates by sale, by another the compulsory services of the peasantry were lessened or commuted for a money payment. Navigation, too, now began to take a wider range, and voyages were performed by English vessels to a considerable distance; to the Baltic, Spain, Portugal, and Italy. Still our intercourse with those Countries was small compared to that with Flanders and Holland, which were sufficiently advanced in Commerce to purchase our wool, hides, and other raw produce, supplying us in return with a variety of manufactured articles.

During the reign of Elizabeth the regulation of our Commerce was committed to Cecil, a prudent, impartial, and, so far as the state of information in that Age permitted, an enlightened Minister. He was very ready to grant exclusive privileges for various branches of foreign trade, such as that to the Levant, the Baltic, Africa, and, lastly, to the East Indies. Such a course, however contrary to our present impressions, was unavoidable in an Age when individuals had little capital, and when, without an assurance of ultimate advantage, they would have been neither able nor willing to incur the expense attendant on the outset of almost every mercantile settlement in a foreign Country.

We pass on to the latter part of the XVIth Century, a time at which England had enjoyed a hundred years of internal peace, and had reaped her full share of the benefit arising from the influx of the precious metals from America. Our towns were still small, and the inhabitants lived chiefly in the country, in villages and hamlets, but their situation, compared to that of their forefathers, was amended in various respects. The amount of the yearly exports and imports had increased; and so also had the personal comfort of all ranks, in food, clothing, and lodging. The dwellings of the middle and lower classes, from being little else than sheds or cabins of wood, were constructed, at least such of them as were new, of stone and brick. This was the era at which floors were substituted for the bare earth in the lower part of the dwellings, and glass became generally used in windows in lieu of the horn and lattices of ruder times.

The XVIIth and XVIIIth Centuries.

During the XVIIth Century, the Western or maritime part of Europe reaped the advantage of former discoveries, and extended its navigation both to India and America. The chief share of this Trade fell to the Dutch, whose situation might be compared to that of husbandmen practised in the labours of the field, and ready to enter on the opening harvest, as they were much more advanced in navigation and productive industry generally, than either the French or English of that Age. There was, however, a continued, though very gradual, increase of our mercantile tonnage, and a strong desire on the part of the Public to enlarge it at the expense of our Batavian rivals: hence our celebrated Navigation Laws.*

Our Navigation Laws.

So early as the reign of Henry VII. there were passed Acts of Parliament enjoining that certain commodities from abroad should be imported only in English ships, manned by English seamen. Half a century later, in the reign of Elizabeth, laws were passed to exclude foreigners from our fisheries and coasting trade; but it was in 1651, and under the influence of Cromwell, that the principal Navigation Law was enacted. Its chief dispositions were as follows.

Merchandise of the growth or manufacture of Asia, Africa, or America, to be imported only in English vessels, of which the master and chief part of the crew are English.

Merchandise of the growth or manufacture of Europe to be imported into Great Britain only in British ships or in ships belonging to the Country in which the goods were produced.

Such was the substance of the Act of 1651. In 1662 it was in some degree modified, and the injunction to import in British ships was confined to certain articles, called on that account "enumerated articles;" but these comprised all goods that were bulky, or of importance with a view to freight, such as corn, timber, hemp, flax, wine, spirits, sugar.

These laws effectually prevented the Dutch from acting the part of naval carriers between England and other Countries, and necessarily increased our mercantile tonnage, the amount of which was raised from 95,000 tons in 1660, to 190,000 tons in 1688.

Trade with North America and the West Indies.

Our North American colonies, in particular New England, Virginia, and Maryland, considerably increased their population and trade in the latter part of the XVIIth Century. The shipping then employed in our intercourse with them, though very different in size, was equal collectively to about 200 vessels of 200 tons each. There was an increase also in the trade of our West Indian Islands, the chief of which at that time were Barbadoes and Jamaica. With all these colonies our principle of intercourse was monopoly for monopoly: we required them to receive their manufactures wholly from us, and to send to England in the first instance almost all the produce they exported; while, in return, we opened to them our market of consumption; and imposed high duties on similar goods when brought to us

* See that head in our *Miscellaneous Division.*

Commerce.

from other parts. Thus the flax, hemp, and ship-timber imported into England from the Baltic were subject to duty, while the same articles from North America were duty free; the culture of tobacco at home was prohibited, in order that our market might be open to the tobacco of Virginia. On the other hand, we required that the rice, sugar, and other produce of our colonies destined for the Continent of Europe should be sent in the first place to England. The colonists were allowed to hold direct intercourse only with the Countries South of Cape Finisterre, *viz.* Portugal, Spain, Italy, the Levant; which not being manufacturing Countries were not likely to compete with us in the supply of finished goods.

Trade with Spanish America.

Towards the latter part of the XVIIth Century, our manufactures having acquired a certain degree of extension, there took place a considerable export of them to Cadiz, for the supply of Mexico and other Spanish colonies. To this was, some time after, added an extensive contraband traffic carried on between those colonies and our West Indian Islands. The Spanish Government exacted a duty on all manufactures imported into America, and was very jealous of intercourse between their colonists and Europeans; but it was found impossible to prevent smuggling along a coast of such vast extent, and within the reach of such active navigators as the English. The occasional rencounters between our contraband traders and the *guarda-costas*, or Custom-house vessels of the Spaniards, led to repeated conflicts, and were one of the chief causes of the destructive war between the two nations, which began in 1739.

With Portugal and Brazil.

Portugal being in close alliance with England, our trade with that Country and her colonies was open and unshackled: they bought from us quantities of woollens, hardware, and other manufactures, giving us in return wine, fruit, and occasionally gold from Brazil.

With India

The nature of our East Indian trade differed materially from that to North America or the West Indies. We made no attempt to colonize India; our exports to it were less in merchandise than in silver; our returns not in produce but in calicoes, silks, and other light manufactures. Of these, the half at least was re-exported to the Continent of Europe, their consumption in England being subjected to a heavy duty, in order that we might preserve our home market for our own manufacturers.

Acts of Parliament relating to trade.

The reigns of Elizabeth, James I., and Charles I. had been the era of monopolies and exclusive grants; but under Cromwell many of these were abrogated. This was a natural result of the progress of trade: the capital, intelligence, and enterprise of merchants having increased, it became fit and even requisite to open to them the field of competition in business. Unfortunately in the next reign, (that of Charles II.) Government lent itself to the urgency of our manufacturers and their partisans in Parliament, so far as to impose heavy duties on foreign goods. There was a general complaint on the part of the Public, that a preference was given at Court to French articles, and our Custom-house returns certainly showed an increased import of the finer woollens and linens; also of silk, paper, and glass from that Country, the total value exceeding a million annually; while the export of English articles to France was comparatively insignificant. This led, in 1678, to Acts of Parliament imposing a heavy duty on a number of commodities from France; a course followed with double vigour after the Revolution in 1688, and the ensuing war; national animosity concurring with the belief that our interests called on us to exert our utmost efforts to discourage the use of foreign articles and extend that of our own. In regard to English goods exported, Government not only returned whatever duties had been previously paid on them, but in various cases granted a bounty on the export. It forbade also the sending abroad our raw materials, such as wool or hides, and half-finished articles, such as undyed cloths, in order that all the work required to complete them might be performed in this Country.

The Mercantile system.

This was the beginning of what is called by Political Economists the Mercantile system; a system which appears in a favourable light to men accustomed to judge from first impressions, and who, conversant only with the practice of trade, have little knowledge of its general principles. Such men form their opinions on a very confined view of things; on the events passing under their eyes, without considering that these are but a few links in a complicated chain. Thus gold and silver were in their view less the representatives of wealth, than wealth itself; and they judged it highly desirable to get as much as possible of both into the Country: hence a preference to a trade, such as that with Spanish America, in which the returns were made in hard dollars. Having become possessed of a certain portion of the precious metals, the next point with the advocates of this system, was to secure our tenure; hence the repeated prohibitions against the exportation of coin. It never seems to have occurred to these reasoners that money, like any other commodity, will find its way into a Country possessing, either in produce or manufactures, articles which its neighbours are desirous to obtain; and that the true plan to bring money into a Country is to favour the increase of such commodities. Now the best method of favouring such increase is to lower duties, abolish exclusive privileges, or otherwise remove the impediments to production. That done, the Legislature may safely trust individuals with the sale of their property, satisfied that wherever there is an abundance of valuable goods, there will be no want of money to circulate them.

Another leading tenet in the Mercantile creed was that we ought to make at home whatever is required for our own consumption, even articles, such as silks, of which the raw material is not of home growth. This might be a very proper rule if every nation manufactured exclusively for itself, and if our power of selling the articles, in which we have an acknowledged superiority, such as hardware and cottons, were restricted within specific limits. But now that the World at large is open to our exports, the wisest plan evidently is to leave manufacturing industry to its natural course. One Country may excel in one branch of a manufacture, and another in another: thus as to silks, the French are superior in fancy articles, the English in several other kinds of silk; and if we can sell the latter to our neighbours, it is evidently our interest to buy fancy goods from them, rather than to maintain an unprofitable competition in making them. Let our general rule be to extend only such manufactures as are best adapted to our national means, such as require an abundant supply of fuel and an extensive communication by canals. These are hardware, cottons, woollens, earthenware, glass; and if we can supply these on better terms than any other Country, we may rest assured that their sale will be so augmented as to afford us ample means for purchasing the articles (and they are not many) which foreigners can supply on better terms than our Countrymen.

The Revolution of 1688 led to our taking a promi-

Commerce. Effect on trade. The wars after 1689. nent part in Continental Politics and carrying on wars, by means of the Funding system, on a scale of expense till then altogether unknown. This had a remarkable effect in several respects on the state of trade. First, the decided superiority of our armed shipping obliged both the French and Spaniards to trade with their colonies by means of neutrals, which proved a great advantage to Sweden, Denmark, and the seaports in the North of Germany. These Northern States benefited also by the increased demand for hemp, flax, canvass, and iron, arising out of a state of war; while from England there was an augmented export of clothing, arms, and other military stores, these forming the most convenient mode of paying subsidies to our allies. The natural effect of the war was to lessen our intercourse, at least our legitimate intercourse with France, for a great deal of smuggling continued to take place between the two Countries; *viz.* in silks and laces from France to England, and in wool and hardware from England to France.

Our inland trade. Such was the state of our foreign trade in the middle of the last century: in regard to our home traffic we are arrived at the period when our inland communications were greatly extended; when our turnpike-roads were improved, and canals began to be excavated. Hence a remarkable increase in the manufacture of several bulky articles, such as glass, pottery, and hardware, which require canals for a double purpose: first to bring coals to the seat of manufacture during the process of preparation, and next to take the goods to market when completed.

As to corn there was not, as in the present Age, an insufficiency in our growth for our consumption; there was in general a surplus and an export of corn during the first half of the XVIIIth Century.

Interest of money. The gradual increase of monied capital in England was indicated by the progressive though slow reduction of the rate of interest. In the middle of the XVIth Century ten per cent. a year was allowed by law, and was the usual rate for money lent on good security. In a century later, under Charles II., money was commonly lent at eight per cent; but soon after 1700 the legal rate was reduced to five per cent. Towards the middle of the XVIIIth Century the current rate on good security did not exceed four per cent.; and in Holland money could be borrowed still lower; *viz.* at three per cent.

Increase of our public burdens. In the hundred years which elapsed between the accession of William III. and the French Revolution England sustained five foreign wars, each conducted on a great scale and at a very heavy charge. Their respective dates were:

From 1689 to 1697.
1702 to 1713.
1740 to 1748.
1756 to 1763.
1775 to 1783.

The sacrifices attendant on such wars may be reduced under two principal heads; waste of capital as shown by the yearly additions to the public debt; and loss of productive labourers, as well from the number who fall in the contest as from the still greater number who are withdrawn from agriculture, manufactures, and mechanical works to the service of Government. Confining our estimate to the former of these heads, to the increase of our public debt, we shall divide the wars during the century in question into three parts; thus,

The wars of King William and Queen Anne lasted nearly twenty years, and added to our debt...	£54,000,000
Those under George II. fifteen years	80,000,000
The American war under Geo. III. eight years..............	104,000,000

Each of these contests was maintained by our Government with great ardour, and with as large a demand on our resources as it was possible to make without depreciating the currency. The waste of life and property was consequently great, but that which took place under William and Anne, was happily, in a great measure, repaired during the long Peace which followed the Treaty of Utrecht. After 1763 the season of relief did not last so long, and the magnitude of our expenditure during the ensuing war with our colonies was unprecedently large; but, on the other hand, there was by that time a great increase in our resources, in our means of augmenting our products and of recovering from the losses and burdens of war. Our canals were then in a course of extension; our towns had increased their population; the farmers were assured of ready sales for their produce at fair prices; the use of Bank paper was becoming more general; the cotton and hardware manufactures were in a state of activity; and as there was an increased demand for coal and iron, our mines for both were wrought on a larger scale. These are substantial constituents of public wealth, and they enabled our Countrymen of the last generation to recover from the gloom produced by that which at first seemed an irretrievable misfortune, the separation of the North American colonies from the Mother Country. These advantages allowed our manufacturers to meet the French and other rivals in foreign markets, and to retain the supply of the United States of America notwithstanding the antipathy of the inhabitants to England.

Next came the Commercial Treaty with France, concluded in 1786, which opened the ports of one Country to the other, and naturally led to a trial of their comparative ability to furnish the great articles of manufacture. The advantage was in most articles on the side of this Country, and the cause of it was not, as was so often contended by Bonaparte and his partisans, unfairness in the conditions of the Treaty, but the superior means of our manufacturers; a cause which still remains in full force, and deters the French Government of the present day, however friendly in its disposition to England, from renewing the open intercourse, or in other words, the competition between the two Countries.

Our financial difficulties were great in 1783 and the following years, but our prospects gradually brightened and our trade became flourishing both at home and abroad. This improvement took place without the interference of Government, for it was assuredly not caused by bounties, prohibitions, or other artificial expedients: it was the legitimate result of our applying capital and industry to improve our national resources. Agriculture prospered although the rise in the price of corn was slight; our shipping was increased greatly notwithstanding its augmented cost. This, with the extension of our manufactures and the increase of our population, afforded a proof that, heavy as our burdens had become, we were not unable to bear them; and that the expenditure in our former wars, although occasionally lavish and often injudicious, had not, as in the case of The period from 1783 to 1793.

Commerce.

Holland, been carried so far as to produce a serious decline in our productive industry.

Subsequent fluctuations of trade.

The danger of such a decline was reserved for the subsequent wars, conducted as they have been with an unexampled profusion of treasure. Various causes concurred to produce this extraordinary scale of expenditure. Our Sovereign was highly popular, while the Revolutionary Government of France, and the military usurpation which followed it, excited during many years the greatest alarm. Mr. Pitt possessed the public confidence in a high degree; but above all, the abundance of money arising from the exemption of the Bank from cash payments removed the usual checks on pecuniary supplies, and rendered money abundant both with Government and the Public. Every department of productive industry felt the advantage attendant on an uninterrupted command of money. The old adage, "War begets poverty, and poverty Peace," ceased to be applicable to England, for all branches enjoyed, or seemed to enjoy, a degree of prosperity hitherto unknown in time of war. The agriculturist was enabled to pay an increased rent; the manufacturer to raise his rate of wages; the merchant found his transactions extend year after year, and professional men in very many cases doubled the incomes which they had received in Peace. No wonder, therefore, that there should be a general belief during the war that the wealth of the Country was on the increase; few persons suspected that the rise of prices and incomes was, in a great measure, nominal; and hardly any could foresee the extent of reaction at a Peace. It was not until lately, that the continued decline of prices and incomes has shown, beyond doubt, the unstable foundation of their increase during the war; and has given warning that a continued state of Peace is likely to bring our markets still lower; probably to the level of 1792.

Grounds of supposed prosperity during War.

The supposed grounds of our prosperity during the war are thus found to have been temporary and fallacious. Our manufactures increased greatly in price, but that was no indication of augmented wealth; it was owing chiefly to a rise in the cost of labour, raw materials, and other constituents of price. Since the Peace the picture has been reversed; the quantities annually manufactured have increased greatly, but the prices have fallen in a still greater ratio: the cause has been the decrease in the cost of the raw material, in the rate of wages, and in the profits of the manufacturer.

Our mercantile shipping presented a considerable increase during the war, but it was in a great measure owing to the amount of tonnage employed by the Transport Board. But of all the branches of our productive industry, our agriculture has placed in the most striking light the difference of prices in War and Peace. Corn and other country-produce continued to rise almost without interruption during the twenty years of War; they have declined with equal uniformity during the eighteen years of Peace. A similar rise and fall has taken place in professional incomes, and if, in the important head of house-rent, the decline does not extend altogether so far, it has been owing to the progressive increase of our population which since the Peace has gained thirty per cent.

This continued decline of the prices of commodities, and the consequent reduction of incomes, has come on our merchants and manufacturers in a manner as little expected, and as little understood, as was the rise of prices and increase of incomes during the War. No subject has occasioned greater differences of opinion, or a greater variety of schemes for the relief of trade. Most of these, when thoroughly investigated, are found to give but slender assurance of the benefit so fondly anticipated by their projectors: nor will merchants of reflection consider it possible that the evils arising from a lavish expenditure during twenty years, can be speedily removed by any plans, financial or commercial, however plausible. We have, however, the satisfaction of knowing that the national resources are on the increase, and that they bid fair to lessen, in the course of years, the pressure now bearing so hard on the productive classes. The first step towards a judicious application of these resources is to acquire an accurate knowledge of our situation, to obtain a distinct view of the origin and causes of our difficulties. For that purpose we shall now subjoin a summary of our Commercial and financial affairs from the entrance into office of the Statesman, from whom the extraordinary fluctuations of the last half Century certainly had their origin.

British Trade and Finances during the Administration of Mr. Pitt.

Mr. Pitt was placed at the head of the Treasury and of the Government in 1784, at the early age of twenty-five. His precocious advancement to this high station was owing to several causes; to his remarkable success as a speaker, to the veneration entertained by the nation for his father's memory, and to an impression that the eminent qualifications of Lord Chatham bade fair to reappear in his son. Our public men have often had cause to regret coming too early into office; and often have they wished undone the favourite measures of their early years. And if such was not the case with Mr. Pitt, it was owing chiefly to the Country remaining at peace during nine years after his accession to office. The course to be followed by a Minister during that period, though difficult, was not altogether so beset with perplexity as at a subsequent date. Several of our present grievances were then, in a manner, unknown. The Corn Laws were then of very limited operation; provisions were dearer here than on the Continent, but not in a degree to affect the success of our manufactures or the comfort of our mechanics. There was in those days no agricultural distress, for though the prices of corn were lower than at present, farming expenses were low in proportion, and there had been no downfal from better times; no return from Bank paper to cash payments; no complaint of having to pay in gold debts contracted in paper. The difficulties of that Age were altogether different: they arose from the discouragement attendant on the recent loss of our North American Provinces, and the low price of our public funds. Several financial reforms were required, but it was extremely unpopular to impose any new tax, to meet the deficiency attendant on such reforms, or to make the revenue exceed the expenditure. The high duty on tea having led to a most extensive system of smuggling, it was very desirable to reduce the duty at least for some years, so as to cut up smuggling by the roots. A determination to that effect was taken, but it required a substantial public advantage to reconcile Parliament or the nation to the taxes granted in lieu, or, as it was called, as a commutation for the tea duty. Some of the taxes imposed at this time by Parliament, in particular the shop tax, Mr. Pitt

The duty on tea commuted.

Commerce. found it necessary to abandon. In a few years, however, his difficulties were lessened by the growing produce of the revenue, consequent on continued peace, increasing population and extending trade. We possess but few statistical documents for the period in question, and the yearly increase of our numbers cannot be considered to have been so high as at present, inasmuch as vaccination was then unknown, and the cheapness of cotton-clothing, which in later years has so greatly favoured the health of the lower orders, did not then exist; but the yearly increase probably averaged one per cent. or upwards. Hence an increase in the portion of revenue arising from consumption As to another material point, the value of our manufactures exported, it rose during the earlier years of Mr. Pitt's Ministry progressively from eleven to fourteen millions; and eventually, in 1792, to eighteen millions a year.

Commercial Treaty with France. One of the first Commercial measures of Mr. Pitt was a Treaty with France in 1786. The speech by which he introduced this Treaty to the consideration of Parliament was replete with sound and liberal views. The conditions of the compact were fair and moderate, and in the different transactions that ensued, a balance of profit accrued to this Country, possessing, as it decidedly did, superior advantages for trade and manufactures. The Treaty thus became unpopular in France, and proved a theme of frequent declamation with Bonaparte, who, to ingratiate himself with the trading part of the French, repeatedly declared that "never would he sign such a Treaty as that which the art of the English Ministers had extorted from the weakness of the Bourbons."

The Sinking Fund. The year 1786 was the era of another measure of Mr. Pitt, which for a long time was much vaunted—the revival of the Sinking Fund. That fund originated above a century ago with Sir Robert Walpole, in whose day our finances differed greatly from their present state; our national debt being under sixty millions, and our public revenue less than six millions a year. The long peace enjoyed by this Country under that judicious and vigilant Minister, added to the operation of even a small Sinking fund, had the effect of greatly raising the price of Stocks, so that in the year 1732 the three per cents were at 100, and in 1739 at 107. As the loans of individuals are affected in their terms by those of Government, the low interest of the public funds caused a low rate of interest generally, of which the monied men complained, alleging that they could no longer obtain a suitable return for their capital. To lessen their complaints, as well as to avoid the odium of new taxes, Sir Robert had no scruple in resorting from time to time to the Sinking Fund for the payment of various public expenses. This example his successors in office showed themselves very ready to follow; and the Sinking Fund, though at no time wholly suspended, was so often trenched on, that it did not discharge above fifteen millions of the public debt in the course of half a century.

Mr. Pitt's measure in 1786, was a revival of the Sinking Fund, nearly as introduced by Sir Robert Walpole, but with various safeguards to prevent the income constituting the fund from being diverted to any other purpose whatever. With that view the whole was put under the direction of a Commission, and the Commissioners were rendered independent not merely of the Ministry, but in some degree of Parliament. The sources of the income of the Sinking Fund were,

1. An annual million to be paid to it out of the taxes, whatever might be the state of the revenue. Commerce.

2. The amount of such annuities payable by Government as from time to time lapsed or expired by the demise of the annuitants. And,

3. The interest of the Stock annually bought up by the Sinking Fund; such Stock not to be cancelled, but to be entered in the books of the Bank in the name of the Commissioners of the Sinking Fund, the dividends or interest on it going in aid of the Fund.

Such was the Sinking Fund of 1786 when brought into full operation; it extinguished annually about a million and a half of three per cent. Stock: that is, the public by paying in taxes a million sterling more than they otherwise would, paid off as much of its debt as reduced the interest by £50,000 a year. This and this only was the arithmetical operation of the measure; but benefit was expected from its principle, from Parliament giving a pledge to the world that the nation, however burdened by taxes, was determined to pay a million a year above the Government expenditure, for the purpose of lessening its debt and keeping up the public credit.

It is needless to enlarge on the flattering calculations Objections to it. of the effect of compound interest, with which Dr. Price ushered in this boasted scheme. The annual million, as well as the other sources of income to the Sinking Fund, were evidently drawn from the pockets of the Public; in other words, they were abstracted from productive employment. The judicious Vauban, when writing on the finances of France, long since told the World, that were Governments wise, they would be sparing of taxes: he said with truth, *L'argent le mieux employé est celui qui le Roi laisse entre les mains de ses sujets.* The Sinking Fund is now little thought of: it has fallen almost into a state of non-efficiency. The question is how far circumstances, in the early part of Mr. Pitt's Ministry, were such as to justify the adoption of the measure, or to reconcile its adoption with the general admiration of his talents. Mr. Pitt was then only in his twenty-seventh year, and could not have reflected either long or profoundly on the sources of national wealth. He had read Dr. Smith's Work, and he discovered in his public speeches a very proper sense of its value; but that Work is not instructive on the subject of taxes. But the great deficiency in Mr. Pitt's elements of calculation was the absence of statistical documents, and of proofs of the tendency of this Country to prosper without any artificial aids. His natural good sense and disposition to view the future in a favourable light, might, and probably did, suggest to him reasons for considering the national prospects as encouraging; but he was ill provided with documents on which to found such an opinion with confidence. If, even at present, our public men have no adequate idea of our growing resources, it need not be matter of surprise that no man of authority in those days should have come forward to say, "Instead of making the nation pay a million a year additional, keep the taxes at the lowest possible amount, and trust to the benefit that will in a few years accrue to the Treasury from a gradual removal of the obstacles to the extension of productive industry." There were in those days no population returns; no evidence that the increase of our towns added largely to the national resources; no proper estimate of the extent of our iron mines; nor of the benefit likely to result from our abundance of coal when applied to steam machinery.

Instead of such views, Mr. Pitt was probably assailed by such suggestions as, "The price of Stocks can be raised only by continued purchases for account of Government, and these can be made only by a Sinking Fund provided with a yearly revenue; the Stockholders desire such a measure, and to the nation at large it will be an indication of vigour; a declaration that we are willing to submit to an extra burden at present in order that we may lighten the burdens of posterity." This was very plausible advice, and would be considered by the multitude as both spirited and judicious. The course of our narrative will soon show the singular measures into which Parliament was led, after Mr. Pitt's death, by the attractive name of a "system of vigour:" so that we need hardly wonder that he, young as he then was, surrounded by feeble coadjutors, and unprovided with the documents requisite to form right conclusions, should have pursued a very different course from that which he would have adopted in mature age and with more correct information.

A main cause of the Commercial and financial embarrassments of this Country, has been the unacquaintance of our public men with the principles of productive industry. Of this ignorance a striking instance was at that time given by Mr. Fox, who, though opposed to Mr. Pitt in so many of his measures, gave his cordial approbation to the Sinking Fund. This he was led to do not from a knowledge of the subject, which he never studied, but from the specious nature of the plan; perhaps from a constitutional confidence which prompted him, without much inquiry, to place a part of the burden on our own shoulders instead of those of our posterity. On the other hand Lord Grenville, so long the colleague of Mr. Pitt, and his professed admirer, subsequently altered his opinion of the Sinking Fund, and has publicly maintained that the measure was impolitic.

The French Revolution.

We are now arrived at the troubled era of the French Revolution; at the time (1792) when the Jacobins became guilty of the greatest excesses, and when the financial relief to be expected from a continuance of Peace seemed, in the view of our Court, and the major part of our Nobility, a secondary object compared to the danger that threatened us if we remained quiet spectators of the commotions in France. Till this time Mr. Pitt had maintained amicable relations with the ruling parties in France, but when they had driven their King from his throne, and declared their Government a Republic, he was called on to come to a decision on the momentous question of Peace or War. His personal wish was for Peace: both the success of his financial measures, and the prosperity of our trade, were connected with its maintenance; but after the murder of Louis, and the invasion of the Netherlands by the French, he assented, and was in a manner obliged to assent, to the alternative of War.

The determination once taken, it was conformable to his character to prosecute the War with vigour; to regard his financial savings as secondary to our military operations; and while he maintained the Sinking Fund as to form, to adopt a course which in fact suspended, and much more than suspended, its reducing powers—a yearly borrowing of money to a large amount. Our navy, and still more our army, had been on a small establishment during the preceding years, but both were increased forthwith. In the second year of the War our expenses were augmented; in the third and fourth year (1795—96) they were further increased, so that the scale of our expenditure much exceeded that of any former period.

In raising supplies the Ministry experienced great difficulty from two causes; first the distress of trade consequent on the high rate of interest, so much of the capital of the Country being required by Government; and next the difficulty of providing for our disbursements abroad, which could not be met in Bank notes but required specie. When a loan was proposed, the anxious question in those days was not so much what was its amount, as what part of the amount would be required abroad. These were the chief causes of the adoption of that measure which distinguished the late wars from all others, and which gave Government a great and long continued, but as the result has shown, a delusive accommodation—the exemption of the Bank from Cash payments. The immediate cause of that measure was a continued drain of gold from the Bank in February 1797; but we may safely affirm, that a step of the kind had repeatedly entered into the consideration of Mr. Pitt and the Bank Directors, as a relief from the grievances under which all parties, Government, the Bank, and the mercantile interest, laboured from the magnitude of our expenditure. Anxious as were the Bank Directors to support Government in the war, they could not, in prudence, strip the Bank of its treasure so long as they were liable to pay cash for their notes on demand. They watched, and were obliged anxiously to watch, the exchanges with the Continent, which a deficient harvest or the remittance of a large subsidy to our allies never failed to render unfavourable to us. In 1795 and 1796, both these causes had been in operation: they had impoverished the Bank as to gold, and had produced the greatest inconvenience to merchants by the difficulty of discounts. Accordingly, no sooner did the exemption from paying in cash take place, than the small notes issued by the Bank were more favourably received by the mercantile body, who hailed the change as the era of their relief, the dawn of a season of abundance. The Bank was now no longer under the necessity of watching the exchanges, or of restricting their advances to either Government or merchants, on account of their stock of cash being limited; they merely looked to the security, to the probability of the bills offered to them being regularly paid when due. The relief thus afforded to the Public was general and complete; it pervaded every part of the Country. Farmers had no longer difficulty in paying their rents, nor householders their taxes, greatly as they were now increased. The price of commodities, whether produce or manufactures, rose year after year; the same was the case with wages, salaries, professional incomes. The War was no longer unpopular, and the financial measures of Mr. Pitt were extolled as the instruments of our political salvation.

Exemption of the Bank from paying in cash.

In this manner were we conducted to the end of the first war with France. Happy would it have been had we understood the precarious and unstable character of a paper currency when not convertible into cash, and had we been aware, that circumstances might, and very probably would, arise, to carry its depreciation to a serious length. During the first year of the War, renewed in 1803, Mr. Pitt was out of office, but in questions of trade and finance his opinion had at all times the greatest weight. An income-tax of five per cent. was proposed by Mr. Addington, and met with

Renewal of war in 1803.

Commerce. very little opposition after Mr. Pitt gave his opinion that to impose it on funded property was no breach of faith with the public creditor. On another occasion in which he dissented from a tax proposed by Mr. Addington, and adopted by a majority of the House, the members saw the Minister appear next day in his place and withdraw the Bill they had sanctioned, doubtless because he considered the dissent of Mr. Pitt as the most serious of evils. Next year, 1804, Mr. Pitt was recalled to office, but his tenure of it was unhappily too short, for in less than two years his death took place, at the early age of forty-seven, and in the midst of our contest with France.

British Trade and Finances since the Death of Mr. Pitt.

The successors of Mr. Pitt in the financial department were first Lord Henry Petty, (now Lord Lansdowne,) and afterwards Mr. Perceval. Both followed up Mr. Pitt's plan of finance, the main feature of which, after the increase of our circulating medium had relieved the wants and increased the incomes of individuals, was "to raise the chief part of the supplies within the year;" that is to borrow less than we had done previously, and to look for the chief provision for our expenditure in high temporary duties; in other words in war-taxes, so called because Government was pledged that they should continue only during the War.

When the Grenville Ministry was removed from office in March 1807, our trade and finances fell under the direction of men who moved in the footsteps of Mr. Pitt, but who, when compared to him as to information and judgment, were distant *longo intervallo.* They had not been a year in office before they discovered an unacquaintance with the course of our foreign trade, a total unconsciousness of the precarious nature of our Bank paper, by adopting a measure which Mr. Pitt would never have sanctioned—the stoppage of neutral navigation. This was effected by the Orders in Council of November 1807, a measure never thoroughly understood either by the House of Commons or the Public. These Orders were expressed in the complex style of law papers, and their true object was kept studiously out of sight, as well it might be, for never was there a Commercial edict less to be justified, or less fitted to bear investigation. The real account of it is as follows:

Neutral shipping; the advantages which it enjoyed.

The War had by that time lasted above twelve years, and had added heavily to the expense of our ship-owners: timber, hemp, wages of seamen were all enhanced, and an extra time was generally required for the voyages of our merchantmen from the necessity of waiting for convoy. From these various disadvantages neutral vessels were free, and their navigation being carried on at less cost, they had an advantage over British shipping which could ill be brooked by the subjects of a Government which commanded the Ocean. Hence repeated attempts on the part of our merchants to cramp their navigation; attempts which had been resisted by Mr. Pitt, and which had no chance of success with Lord Grenville. But the case was very different on Mr. Perceval coming into office: from his professional habits, he was necessarily unacquainted with trade, and had unfortunately given his confidence to those lawyers and merchants who were most clamorous against neutrals. No sooner, therefore, had our attack on Copenhagen in the Autumn of 1807 succeeded, than the party in the Cabinet, whose creed was a "system of vigour," urged, and in despite, as was said, of the opposition of Lord Hawkesbury, obtained the adoption of the Orders in Council against neutral navigation. They prescribed that "neutral vessels, whithersoever bound, should put into a port either in England or in one of our dependencies, there to pay certain charges and receive a license or sanction for the continuance of their voyage." Such an edict was not, in point of form, so strong a measure as a direct stoppage of neutral navigation, but the authors of the Orders doubtless anticipated that they would have that result, particularly in the case of the Americans; as a nation claiming to be independent would hardly submit to such an acknowledgment of inferiority. The consequence was, that the American Government prevented their merchant-vessels from going to sea, and a general suspension of their navigation took place.

Commerce. Stopped in November 1807.

Consequences of this stoppage.

The effects of this suspension on the trade, the credit, and the finances of this Country were pernicious in a high degree; much higher, indeed, than is even yet known to the Public, for the evil was not at once apparent; it came on us indirectly and covertly. First, as to our Bank paper, the American merchants had been highly instrumental in maintaining its credit in the following manner. They sold every year to France, Holland, and the rest of the Continent of Europe produce to a large amount; larger by three, four, or five millions than the value of the goods they took from those Countries in return. In what manner was this balance disposed of? It was paid to the Americans in money, and was sent over by them from the Continent to England, where it was applied to pay our merchants and manufacturers for the very large quantities of goods which they sent yearly to the United States. The Americans were thus the medium, or rather the cause, of *continued remittances to this Country in money or bills of exchange;* this had been the case every year since the Bank exemption in 1797, and serves to explain a fact which had surprised ourselves almost as much foreigners; *viz.* that our Bank notes should escape depreciation so long after they had ceased to be payable in cash. By stopping the navigation of the Americans we deprived ourselves of this important resource. Instead of buying our manufactures, they were obliged to manufacture for themselves, to the incalculable injury of our woollen and cotton trade; while from the Continent of Europe they could make us no more remittances because we had precluded their intercourse with Holland and the other Countries which supplied them.

Our Bank notes depreciated.

The consequence was a rapid fall in the value of our Bank notes compared to coin, at first of ten or twelve per cent., afterwards of fifteen, eventually of twenty per cent., and upwards. Other causes, it is true, cooperated to produce this unfortunate result, in particular our military expenditure on the Continent, and the large amount of specie sent abroad to buy corn; but these would have been, in a great measure, counterbalanced by remittances from the Americans had they been allowed to continue their trade. Unfortunately Mr. Perceval and several of his colleagues continued to think differently; the Americans bore their grievances in peace during four years, but at last, in June 1812, they declared war against us. In vain did Lord Liverpool repeal the obnoxious Orders almost immediately after Mr. Perceval's death: the Americans mistook his motives and persisted in the war. It lasted nearly three years, and if we make a computation of the loss of property caused to us from

Commerce. first to last by this unfortunate quarrel, first, by the failure of Americans who were largely indebted to our merchants; next, by the depreciation of our Bank paper; and lastly, by the war with the United States, we shall find the aggregate to be little short of two hundred millions sterling; that is, of the twenty-eight millions which we now pay annually for the interest of the public debt, no less than seven or eight millions are to be traced to our unfortunate stoppage of the trade of neutrals during the last seven years of the war!

The year 1812 was a season of trial for our finances: the war in Spain was at its height in point of expense, while Russia required all the pecuniary aid we possibly could afford her. Next year, 1813, called for still greater efforts: the chances were now in favour of our allies, and never could our resources be better applied than in their support. It became necessary to trench on the Sinking Fund: Ministers did so, but in an indirect and disguised manner. They thought it essential to have the appearance of maintaining the integrity of the Fund, and it will hardly be believed that at the time a large sum was drawn from it, there issued from Lord Bexley's office a printed paper gravely stating that the reduction of our debt would proceed more rapidly after making this abstraction, than on the former plan which abstracted nothing. So strange a misrepresentation seems almost incredible, but in truth the history of the Sinking Fund contains a series of misrepresentations quite unworthy of the Government of a great Country, and to be palliated only on the ground that, during an arduous struggle, Ministers may be permitted, for the sake of keeping up public credit, to resort to steps which in time of Peace would be altogether inexcusable. Nearly half a century has elapsed since the Sinking Fund has been held forth to the Public as our financial sheet-anchor, the instrument by which we were to be relieved from the pressure of our debt; yet the actual *bonâ fide* reduction effected by it during all that period has not exceeded thirty millions!

Part of the supplies of the Sinking Fund appropriated to the war.

It is now above twenty years since the date of our Second Population Return, which established beyond all question the progressive increase of our numbers and resources. From that time forward Ministers were relieved from the necessity of artificial expedients; fortified by such a document, it would seem that they had merely to declare to the Public that the repayment of our debt was no longer requisite, and ought not to be attempted; that the great object was to favour the extension of our productive industry, by which means our debt, though the same in numerical amount, became less in proportion to the collective funds of the nation. At times, Ministers appear to have been actuated by such views, having repealed several taxes on account of the injury they caused to trade and manufactures, such as those on salt, on coals, on hemp and silk, and the tonnage duty on shipping: but much that was injurious remained.

The occasions on which the financial knowledge of the House of Commons was chiefly put to the test were in 1811, in the discussions on the Bullion question, and in 1819 on the resumption of cash payments. What an inattention to facts did these discussions discover! how scanty a knowledge of Statistics! how great a tendency to adopt plausible theories and to hasten to premature conclusions! The causes are that the mercantile Members of the House are little in the habit of public speaking; while of the other Members, the major part are unacquainted, not merely with Commerce, but with the principles of productive industry generally. Our great Universities, at which so many of the Members have received their education, have not till very lately possessed the means of instruction on such subjects; and of the Works hitherto printed on Political Economy the chief part are obscure, intricate, abounding in theories, and deficient in practical illustrations.

Having now brought down our narrative to the close of the last War, we shall in the next place endeavour to explain,

1. The sources of our high prices and large financial supplies during that War; and

2. The causes of their diminution since the Peace.

Singular it certainly is, that in a Country in general so enlightened as this, we should still be in doubt as to a subject so nearly regarding us, and in respect to which the opinion of the Public ought long since to have been fixed. But neither our merchants nor our public men are by any means agreed about the causes of these fluctuations. The inquiry is long and complicated, and those who, from their official situation, were best fitted to cast light on the subject, have been either prevented by pressure of business from probing it to the bottom, or have been unwilling to speak out as to a course of policy, which, since the general reaction, has been viewed unfavourably by the Public, and led them to censure severely the management of the War.

To go back to the years 1790, 1791, 1792. This Country was then in profound peace, and, if there were occasional complaints, as at present, of over-competition, the condition of our trade, manufactures, and agriculture was, on the whole, satisfactory. The interest of money was moderate, and capital might be borrowed on fair terms to carry on any judicious undertaking; but there were few examples of sudden rise of price, and few Companies whose stock or shares formed an object of speculation on the Stock Exchange. This tranquil condition of our national industry, this medium between activity and stagnation, underwent a material change as the War proceeded, and as our public establishments were increased. The large demand for money by Government in the shape of loans, raised the rate of interest, and led to the suspension of many undertakings, such as canals, buildings, manufactories, for which abundant capital and a low rate of interest are indispensable. Hence the discharge and non-employment of a considerable number of persons, partly in the middle, more in the lower ranks. But that was soon balanced, and much more than balanced, by the new employment arising from the War, first in the army, the navy, and the Civil service of Government; and next in the supply of arms, clothing, naval stores, repairs of shipping, building of barracks, and the performance of many other contracts. That these employments were of great extent was evident at the time to all who had the opportunity of personal observation, and is equally evident to others, by the unparalleled expense of the war, which beginning at twenty millions sterling a year, extended progressively to thirty, forty, and eventually to upwards of fifty millions a year.

State of the Country in 1792.

Effect in War of public loans and of large levies of men.

The number of men withdrawn from productive industry, and employed in the army, navy, and militia, was great beyond example. Already, in the year 1804, they amounted to 400,000 under arms, to whom we may add at least half as many for the manufacturers of clothing and arms, the shipwrights, the importers of

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naval stores, the performers of contract work for Government under various forms; making in all 600,000 men employed for account of the Public. This very large number was drawn from the able-bodied part of the population, who would otherwise have been added to our farming labourers, our mechanics, our manufacturers; in the same manner as the officers in the army and navy, and the *employés* in the Civil offices, were young men who would otherwise have been occupied professionally or commercially. Hence a great demand during the War for the service of individuals in the middle as in the lower ranks; a rise in the rate of wages, salaries, and the price of commodities in general; together with a ready engagement for almost all, high or low, who were able and willing to work. Many who, from deficient activity or mediocrity of parts, would in a state of Peace have remained unemployed, were brought by the War into situations attended with income; many of them in the public service, others in that of individuals. No wonder that under such circumstances the means of rearing a family should be augmented, and that our numbers should continue to increase. The waste of War was little felt in comparison with the number (250,000 or 300,000) added annually to our population. The rate of increase was greatest in towns, the higher wages inducing many thousands of the country youths to become mechanics and manufacturers. Now in towns, particularly in the larger towns, the working classes being so much better paid than in the country, can afford to live better, and to consume more articles productive to the Exchequer. They wear better clothing, consume more animal food, as well as more groceries, beer, and other exciseable articles. These details, homely as they are, require to be stated, because the consumption of the lower orders forms a material part of the revenue, and our object is to show in what manner and from what causes, the public income increased in so remarkable a degree during the War.

Increase of the revenue during the War.

Our taxable income.

It may be useful to attempt a short sketch of the heads of our taxable income. It consists first of the income of the upper and middle classes, and next of that of the better paid portion of the lower orders, the whole coming under the following heads:

Rent of land;
Rent of houses;
Dividends from the public funds;
Pay of the army, navy, and public offices;
Income from trade and professions; and, lastly,
The wages of the better class of mechanics and manufacturers.

Now the effect of the War and of the extended circulation of Bank notes was a great increase in the pecuniary receipts of individuals; in the rate of wages, salaries, and the price of commodities generally. This, in other words, was so much added to the money amount of the national income subject to taxation. In 1792, before the War, our national income, subject to taxation, appears not to have exceeded in money one hundred and thirty millions sterling;

Its great increase.

But in 1806, after thirteen years of war, it had risen to two hundred and twenty millions;

And eventually, in 1813, after twenty years of war, to three hundred millions!

Such was the extraordinary result of a War, conducted chiefly by means of Bank paper. In former Ages the small Republic of Holland, which, compared to other Countries, seems little more than a speck on the Map of Europe, maintained long and expensive struggles with powerful States, in particular with Spain and France; but the scale both of the revenue and public debt of Holland was but a miniature of that of England. But how were we enabled to continue so long and so enormously expensive a contest? Because, of this vast outlay nine parts in ten, or rather nineteen parts in twenty, were little more than a *circulation;* a reissue to the Public for clothing, stores, the pay of the army and navy, and other heads of expenditure, of the very large sums drawn from the Public by loans and war taxes.

Thus the Treasury received from the tax-gatherer and loan-contractor a given sum; it reissued the same in payment of stores, of personal service, or of the interest of borrowed money; and the respective parties, thus receiving sums from the Treasury, paid back great part in excise and other duties. Our taxes and our expenditure were thus a continued circulation, and had they not been so, neither this nor any other nation could have withstood them for two years; but the difficulty is explained from the time at which we see the Exchequer returning with one hand what it had received with the other; particularly when we find that no less than twenty millions a year of our expenditure were at the charge of posterity; that is, the money borrowed yearly during the War was on an average twenty millions; so that the circulation of that very large sum stimulated our productive industry without any other burden at the time than that of the interest.

Charging and countercharging in trade.

It may be useful to explain what is meant by an expression which is applicable to persons in trade under any circumstances, but particularly under such as we are now describing. The rise which during the War took place in the rate of wages, joined to a rise in the price of raw materials, such as wool or flax, led necessarily to a rise in the price of the finished article; that is, the manufacturer charged to his customer the additional sum he had been obliged to pay to his workman and to the grower of the raw material. The purchaser naturally objects to this extra demand or not, according as he may find difficulty in charging it again to the exporting merchant, or to whoever buys from him. But, at a time when prices generally were on the rise, there was little objection to an augmented charge; the principal point was to obtain the goods. In like manner our farmers, receiving a higher price for their corn and cattle, had no objection to pay back a part of their new profits to the different shopkeepers and tradesmen from whom they received supplies. It was thus that the extra price paid in one stage of a transaction was repaid to the disbursing party in the next; charging and countercharging went on in a circle; and with comparatively few objections after the exemption from cash payments in 1797 made money permanently abundant.

Such were the causes of that remarkable state of things in which our resources seemed to increase year after year with the demands on them, and the magnitude of our financial means were as much an object of surprise to ourselves as to the nations of the Continent. But so unnatural a combination of circumstances could not last; the War came to an end, and with it our loans and War-taxes. Our army and navy were reduced; the militia ceased to be embodied; the contracts for stores were greatly lessened. The thousands and tens of thousands of able-bodied men lately drawn away for the public service, were now left quietly at home and allowed to follow a productive employment. Hence a general fall in

The Peace and general fall of prices.

Commerce. the price of commodities, followed by the non-employment of very many persons, and by reduced wages to those who were kept at work. Corn, which had so long fetched a high price, now fell thirty and forty per cent.; the fall was equal in other articles, such as timber, hemp, flax, in every thing, in short, of which the import from abroad, long prevented by the War, was now open and unrestricted. The consequence was the failure of many thousand persons, whether agriculturists, merchants, or manufacturers, and a general complaint that though the income-tax, amounting to so much as fifteen millions a year, was taken off, the pressure of our public burdens was felt much more severely than during the War. In fact, the Public have had since the Peace as much or more difficulty in paying fifty millions a year, as had been felt in paying seventy millions during the War.

Never was there a more unexpected result. Our public men, far from anticipating financial embarrassment at a Peace, had considered it likely to be, what Peace had generally been in former Ages, a season of relief. The War had lasted so many years, that few either of our Ministers or our merchants, preserved an adequate recollection of a state of Peace. Sir Francis Baring, and the men of his day, who had witnessed our financial difficulties at the end of the American War in 1783 and 1784, were no more; we had lost Mr. Pitt also, who, as he was the only Minister who could have prevailed on the nation to incur such an enormous expenditure, was the only one capable of devising measures for lessening its eventual pressure. Lord Liverpool, Mr. Huskisson, and others of our public men who gave, or rather endeavoured to give attention to such subjects, (for the urgency of current business is too great to enable men in office to think either long or profoundly on a difficult subject,) had not, from their time of life, witnessed the state of our trade and finance at the close of the American War. The consequence was that things were left to their natural course, and no step was taken by Government to lessen the reaction, or to relieve the classes more particularly exposed to its pressure.

Not understood by our public men.

Lord Lauderdale, who had studied Political Economy, and had given a great deal of attention to the Bullion question, foresaw in the last year of the War a part of the approaching reaction. He stated in Parliament, that since the depreciation of Bank paper, twenty shillings of our currency were worth no more than fifteen in gold or silver, and he recommended that, on returning to cash payments, existing contracts should be adjusted in that proportion. There could be no doubt of the propriety of our returning, as soon as at all practicable, to cash payments, and of our getting quit of so glaring an irregularity, as that of Bank notes not convertible into coin; the question was on what terms, on what proportional scale, the reinstatement of our currency ought to take place. Had Parliament foreseen the general decline of prices that has taken place, they would probably have listened to the admonitions of his Lordship, and of others, who entreated them to pause before engaging to pay in cash without deduction, the enormous sums that had been borrowed in paper. But the close of the War was a time of general excitement; we had fought our battles with success; we had accomplished the deliverance of Europe; we had reduced France and her proud ruler to their level; and among so many subjects of self-congratulation we were little disposed to listen to unfavourable views, or to adopt negative measures. There was a general expectation among merchants, as among Members of Parliament, that the depression of trade would be of short duration; an impression which the course of events has been far from confirming.

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Fluctuations in our Trade since the Peace.

The overthrow of Bonaparte in 1814, reopened to our trade the Netherlands, France, Italy, Denmark, in short every part of the Continent from which he had excluded our merchandise during several years; that is, from the time that he had thought fit to enforce the execution of his insane anti-commercial edicts of Berlin and Milan. These prohibitory decrees were coincident in point of time with our stoppage of the American trade, and under the joint effects of the two, the prices of various articles had risen to a height almost unknown in the History of trade; tea selling on the Continent for ten and twelve shillings a pound, sugar for five and six shillings. This had led to very singular expedients, such as conveying groceries and other articles into Germany by land, unloading them first at Salonichi in Greece, and carrying them, on the backs of mules and horses, through Servia and Hungary, into the heart of Germany, a distance of nearly two thousand miles. Such was the miserable waste of money and labour consequent on the struggle between the two Governments; our Ministers having put an end to the navigation of neutrals, and Bonaparte being determined that British shipping should not take their place. Happily the overthrow of his armies, first in Russia, afterwards in Germany, burst the chains by which he fettered the activity of merchants, and opened the Harbours of both the North and South of Europe, to our exports. But, as usual, the ardour of our merchants carried them too far, for they had no adequate idea of the impoverishment of the Continent. Looking on the Map at the vast extent of coast, and at the number of large cities now re-opened to our trade, our speculators considered, that if England alone consumed annually above 15,000 tons of tea, and 150,000 tons of sugar, the consumption of the Continent must be at least equal. Of the success of these adventures, the speculators had no doubt; their anxiety was to lose no time; to be the first to arrive in the Continental markets. The result however was, in general, unfortunate; the foreign buyers were wholly unable to pay the price required to indemnify the shippers in England: and since it was necessary that sales should be made, they were made at a ruinous sacrifice.

Exports to the Continent in the year 1814.

Such was the state of our foreign trade at the end of 1814. The year following was ushered in by the news of the Peace between England and the United States of America, which opened or seemed to open a great market for our manufacturers. This was a new field and regarded a class of our traders quite distinct from those who had suffered by the exports of the year before. They were, however, as full of ardour as their predecessors, and, on referring to the Custom-house returns, we find that the quantity of British goods sent abroad in 1815, was great beyond example. But the result was very unpropitious, and our merchants were now taught to their cost how greatly our Government had erred in stopping the American navigation during so many years. By doing so they had impoverished our Transatlantic customers in nearly the same manner as Bonaparte, by his tyranny, had impoverished Holland, Prussia, and

Exports to the United States in 1815.

other parts of the Continent. The selfish and headstrong enthusiasts in this Country who, in 1807, had prevailed on our Ministers to issue the Orders in Council against American navigation, had no idea of the extent of the mischief that would recoil on ourselves.

The result unfortunate.

For all this we suffered severely in 1815 and 1816; our only satisfaction was that the very low prices at which our goods were sold in the United States, checked the new establishments in that Country, and showed how unavailing it was in a quarter wherein labour is so high-priced, to enter into competition with the manufacturers of England.

Next came the overthrow of Bonaparte at Waterloo; an overthrow so complete as to give assurance of a general and long-continued Peace: hence a great reduction of the military establishments in every Country in Europe; the return of many hundred thousand men to productive employment, and a general fall in prices. Was it then matter of surprise, that so great and sudden a transition should have produced that general stagnation of business; that want of work for the lower orders; that pecuniary embarrassment in the middle and upper ranks, which will so long mark in gloomy colours the year 1816? Corn and country-produce had been at low prices during two years; many of our farmers had failed; many others were paying their rents out of their capital. Among merchants and manufacturers the decline had been equally great; and men inquired anxiously of each other from what unknown cause the high prices and prosperity of a state of War had been succeeded by such general impoverishment. On this occasion, however, our distress did not last long; favourable exchanges brought us large sums of gold and silver from the Continent; the Bank of England, and, in consequence, the private Bankers, were at ease as to money; and the bad harvest of 1816, though productive of extreme suffering to many of the lower orders, gave the farmers assurance of high prices for a certain period to come. This operated as a stimulant to the employment of country-labourers; and the course of circumstances led to a corresponding revival of industry in towns.

General distress in 1816.

Revival in 1818.

Circumstances were similar during the year 1818; the demand for workmen and the rate of wages progressively advanced; funded property rose in price; the case was the same with landed property, so that this proved the most stirring and apparently prosperous season we had had for many years. It is necessary to say "apparently," because unfortunately the high wages and high prices of this interval, its large sales and liberal profits, were of short duration. Trade had, as usual, been overdone; we had imported of various commodities more than we could turn to account at the time; the speculators, at least the needy part of them, were unable to wait; goods were forced on the market, and the result was a series of losses, insolvencies, and bankruptcies. At that moment, Parliament decided on the resumption of cash payments; and although the act was prospective, and allowed the Bank considerable time to effect the change, there prevailed from that time forward, among merchants as among agriculturists, an apprehension that they would be straitened in pecuniary means, and that the prices of commodities could not be otherwise than low.

Low prices in 1819 and 1820.

The years 1819 and 1820 were thus passed in a languid, discouraging manner; in the latter the harvest proved uncommonly abundant, and the price of corn and country-produce experienced a fall. This tended greatly to the relief of mechanics and the lower ranks in towns, but as greatly to the injury of farmers, who declared loudly that with such low prices it was wholly out of their power to pay their rents. Hence the appointment, by the House of Commons, of a Committee on the state of agriculture, which sat many weeks, examined a number of witnesses, and made a long and comprehensive, though by no means a perspicuous Report. The writers of that Report took a historical view of the state of the landed interest for more than half a century, and enlarged on the prosperity which had always attended it when our merchants and manufacturers were thriving. The inference was, that the interests of traders and landholders were identified; and that it would be vain to expect relief to the one by imposing a burden on the other. The agriculturists complained of the pressure of taxes; but the Report forbade any attempt at trenching on the property of the fundholder, and encouraged the landholders, at least that large proportion of them who had to pay interest on borrowed money, to expect relief from a very different cause; from the probable fall in the rate of interest, the state of the money-market indicating an approaching reduction from five to four per cent. The expectation thus held out was realized to a considerable extent, monied capital became abundant; and in the course of 1822 and 1823, a general reduction of the rate of interest took place.

Committee on Agriculture in 1821.

Monied capital becomes abundant.

This abundance of monied capital continued and produced its usual effects; a general rise in the value of funded property, which led many persons to sell out and invest their money in various undertakings, such as the purchase of land, building houses, improving roads, or excavating canals. All this tended to create work and excite a general activity. Add to this that the price of corn having at last experienced a rise, the farmers were in some measure relieved, and enabled to circulate money as well by employing more labourers, as by making purchases from tradesmen and manufacturers in towns.

Its favourable effect on trade.

The Commercial tide was now turned in our favour, and the year 1824 proved eminently prosperous. It was marked by a continued rise in the price of funded property, a general briskness in our markets, and a considerable surplus in the public revenue. The abundance of monied capital led to the formation in that year of numerous Joint Stock Companies. One of the first of these was the Alliance Insurance Company, the stock or Shares of which rose to a premium, not so much from expectation of large profits, as from the wealth of Mr. Rothschild and other leading parties in the direction, and from general confidence in their management. Next came the formation of several Mining Companies in connection with Mexico, and one with Brazil. This took place at a time by no means favourable to prudent management, for whenever money has been long abundant, the feeling engendered partakes more of confidence than is fitted to commercial enterprise. The Mining Companies formed in the first instance proceeded on fair grounds; on information which, though very imperfect, had for its basis to engage only in mines of good repute. For a time the stock or Shares of these Companies bore a moderate premium: it was not until the latter months of the year (1824) that their price began to give evidence of an abuse of prosperity. It then rose week after week, not from the receipt of any intelligence of consequence, but from the continued

Joint Stock Companies in 1824.

Commerce. abundance of money and from the puerile and visionary feelings which influence the Stock Exchange, where, whenever circumstances have been for some time favourable, the example of a few leading purchasers is so often followed by the mass with indiscriminate eagerness.

The year 1825.

We are now arrived at the memorable 1825, a year in which the spirit of speculation in this Country reached a height that rivalled the excitement of the Mississippi scheme in France, or of the South Sea Company, a century ago, in England. What were the causes of such infatuation among merchants, who, in general, had considerable experience, and had witnessed the evils of reaction in the money market? It was to be ascribed to a concurrence of flattering circumstances,—to abundance of monied capital, a confidence that such would continue, a progressive rise in the public funds, and an exaggerated notion of the wealth of Mexico and Peru. The real circumstances of Mexico were little understood in England, or in any part of the North of Europe. The persons who had emigrated from Mexico after the Civil War, repaired not to this Country nor to our West Indian Colonies, but to Cuba, Bordeaux, and Spain. Cadiz and the smaller maritime towns in Spain connected with Mexico in trade were the proper quarters to obtain information; but of all the Mining Companies then formed, not one thought it necessary to resort for admonitory instruction to so distant a quarter. Their Directors had before them the flattering statements of Baron Humboldt; they had a vague but highly favourable notion of the productiveness of the mines of Mexico and Peru; and they had very little experience of the manner in which one sum of money after another is absorbed in those hazardous undertakings.

The managers of these Companies were almost equally in the dark in regard to points of vital importance at home. The abundance of money in this Country was great, but was it likely to continue, or did it not proceed in a great measure from the issues of Banks, issues necessarily uncertain and liable to be recalled whenever the course of exchange should carry our gold abroad? Questions such as these were unfortunately not put by one merchant to another; for deliberate inquiry and sober calculation were overlooked in the continued rise of funded property and of almost all articles of merchandise. Men began to think that abundance of capital was natural to a state of Peace, and that the difficulty would be in finding the means of investing it. Hence the large sums so precipitately lent to the South American States, which, whatever may be their eventual prosperity, are at present thinly peopled, badly governed, and, in many respects, in the infancy of their productive industry.

Such was our connection with Spanish America in 1825. It had absorbed a large amount of British capital; but the great cause of pressure on our trade at the end of that year, and the origin of the unfortunate panic, was of a different nature: it was to be sought in the purchase and import, on an extravagant scale, of foreign goods, such as cotton, wool, silk, and timber. This took place in the following manner. It is usual at the end of the year for brokers in colonial produce to report to their various friends and connections, in a printed circular, the state of the home market, and the amount of the expected supply. The import of cotton having been less in 1824 than in preceding years, and the stock on hand not great, it occurred to certain speculators that this bare state of things, joined to the great activity of our manufactures at Manchester and elsewhere, was likely to cause an insufficiency in the supply and a consequent rise of price. Hence extensive purchases of cotton were made in the Liverpool market in January 1825, and orders for further purchases were sent out to various foreign Countries; to Carolina, Georgia, Brazil, and even to the East Indies. Silk and a number of other articles were ordered in like manner; not that the supply was actually deficient but that it might become so, in the event of our consumption proceeding in an increasing ratio.

Purchases on speculation in 1825.

The Public were then altogether in a state to be operated on by stimulants; the prices of almost every article of merchandise had risen progressively during the preceding twelve months: hence an expectation that they would continue to rise, and that purchases made at almost any price would be attended with profit. Hence also orders were sent abroad to buy up, not only cotton, but wool, silk, and other articles; and as these orders were conveyed in the private letters of merchants, and accompanied by no act of publicity, engagements were unfortunately contracted to a great amount before one merchant became aware of the extent of the purchases of others. Suspicion of the extent was first entertained by the underwriters at Lloyd's Coffee-house, who saw in the insurances offered to them an evidence of imports to an unprecedented amount. This took place in the Summer months, but the magnitude of the purchases did not become known until the Autumn, when the goods reached this Country, and were reported at our Custom-houses. The sums to be paid for these imports were immense, the goods having been in general bought at high prices. Hence a continued drain of gold from the Bank, the export of the precious metals amounting repeatedly, in this year of wonders, to so much as a million sterling a month.

Particularly in foreign goods.

Our gold exported.

A few cautious persons had conceived alarm from a very different cause. A number of London Bankers used during the War to have discount accounts at the Bank of England; several have continued them since the Peace, but first-rate Bankers make it a rule to avoid discounting at the Bank, their own reserves being in general sufficient. But in this singular season it was observed that Banking-houses of the highest character, houses which had hardly ever been known to apply to the Bank for discount, found it necessary to do so. The cause was the continued demands on them by the country Banks in their connection: the alternative for the London house was either to withhold aid from the country Banks at the risk of making them suspend payment; or to afford supplies, by submitting to send in bills for discount at the Bank of England. They preferred the latter, and supported the country Banks, so that, though a number of the latter found their funds lessened during the Summer, no failure of consequence took place among them till the latter part of the year.

Distress of our Banks.

Many persons were surprised to find the scarcity of money begin in the country, having expected it would have shown itself first in London. But, in fact, the drain of gold was great in both at the same time; that it was not earlier felt in London was owing to the large amount of treasure in the coffers of the Bank of England, the accumulation of four years of favourable exchanges.

Such were the chief causes of the two great mercantile convulsions (1816 and 1825) which have taken place

Commerce. in this Country since the Peace. More than seven years have elapsed since the latter and the greater of these convulsions; but there has occurred in that long interval little to call for remark in this summary, because, in a commercial sense, its character has been nearly uniform; *viz.* sales and purchases of merchandise have taken place to a great extent, but almost always at low prices. One part of our Custom-house books exhibits the quantity, another the value of our exports: in the former there has been a progressive increase; in the latter an equally regular decline; the consequences to be expected from long continued Peace, and open intercourse with Countries in which the rate of wages and cost of subsistence are lower than in England. To put this in a clear light, we exhibit in opposite columns the respective effects of Peace and War on the price of commodities.

Effects of Peace and War on the price of commodities.

War.	Peace.
The rise of prices during the War was caused as follows: *	The fall of prices since the Peace has been caused by,
1st. The demand for men for the public service raised the rate of wages, and the demand for money raised the rate of interest, both of which tended greatly to raise prices.	1st. The cessation of the demand for men and money for the public service.
2d. The insufficiency of our crops caused by an unusual number of bad or indifferent seasons, (*viz.* 1794, 1795, 1799, 1800, 1804, 1809, 1811,) and by the obstacles to import from the Continent.	2d. Since the Peace the number of bad or indifferent seasons (1816, 1828, 1829, 1830, 1831) has not been so great; and the only obstacles to import from the Continent have been our Corn Laws.
3d. The increase of taxation.	3d. The taxes have been reduced by more than twenty-five millions a year since the peace.
4th. The great expense of freight, insurance, and other charges on the import of foreign goods.	4th. Freight, insurance, and other import charges were reduced more than half by the peace.
5th. The depreciation of our Bank paper, particularly in the last five years of the War.	5th. Our Bank paper rose to a par with coin in 1816, and, with the exception of one interval, (1818 and 1819,) has ever since maintained an equal value.

Much has been said of the fall in prices in England from the contraction of our paper currency, and of their fall in Europe generally, from the reduced supply of the precious metals during the last twenty years. Each has been serious in its operation; but the great and overpowering cause of the decline is the absence of a demand by the Governments of Europe of either men or money for the purposes of War; the restoring to productive employment the many millions of capital, the hundreds of thousands of able-bodied men who were formerly withdrawn from it. The prospects in regard to the price of commodities, of every class, whether agriculturists, manufacturers, or merchants, are all mainly dependent on the probability of continued Peace. Any plan for the relief of the productive classes, for lessening the pressure which has long borne, and still bears, so hard on them, must have reference to and depend on the prospect of the nation in that respect. We shall, therefore, bestow a few paragraphs on an examination of this question: on the causes of the Wars which during the last century and a half have so seriously affected our commercial situation; and on the circumstances which justify a hope of their less frequent occurrence in future.

Prospect of continued Peace.

Causes of former Wars.

It was not until the Revolution of 1688 that this Country took a decided part in Continental politics, and began to carry on Wars on a large and expensive scale. This sacrifice our increasing resources fortunately enabled us to make, and it was strongly called for by the state of foreign politics. Louis XIV. had acquired a preponderance which threatened the independence of Europe; Germany and Holland were unable to keep that restless Prince within bounds; an extended coalition was required; and England was invited to be one of its leading members. In our own days, a similar dread, first of anarchy from the Revolution, afterwards of a general usurpation by Bonaparte, led us to make unparalleled sacrifices in opposing France. But circumstances are now greatly altered: France is still suffering from a series of disastrous contests, and has a population sorely divided in political feeling. Peace is indispensable to heal the wounds inflicted by the Revolution and the tyranny of Bonaparte, while as to national union the present generation and probably the next must pass away ere it can be restored. And even were there to arise in France a Government inclined to War, the power of that Country compared to ours is no longer such as to be a subject of serious alarm. A century ago, Great Britain and Ireland bore to France, in point of population, the proportion of only 45 to 100; nor was the proportion of national income much more in our favour; but so much greater has been the ratio of our increase in the last hundred years, that, in population, we now hold the proportion of 75 to 100, and in taxable income of 100 to 100. These are not mere calculations on paper; they are actual results founded on substantial and permanent grounds; on the advantage of our insular position; our extensive canals; our mines of coal and iron; our superior capital; our formed habits of industry. These have been the causes of the surprising increase in our resources during the last century; and they promise a still greater increase in that which is now in progress.

Surprising increase of our resources.

At what period did the effects of this increase in our wealth and numbers become apparent in our military exertions? To pass over the brilliant era of 1759, when the talents of Lord Chatham may be considered to have turned the scale in our favour, and to fix our attention on 1778 and the following years, when France, Spain, and Holland had taken part with America against us, we found our resources, though wielded by so feeble a Minister as Lord North, sufficiently great to conduct us with honour out of the contest. In the Wars of the present Century, the surprising increase of our national

* See in the Supplement to the *Encyclopædia Britannica*, the heads *England* and *France*.

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means was put beyond all doubt, and in fixing the conditions of the Treaties of Peace of 1814 and 1815, our Ministers gave an assurance to the World, that they no longer thought it necessary for the safety of England that the power of France should be impaired. On those occasions, our allies would readily have effected a dismemberment of her territory, by separating from her such Provinces as Alsace, Lorraine, Franche Comté, and French Flanders: but our Ministers knew the augmented strength of this Country, and that France was no longer an overmatch for us. Instead, therefore, of seeking to weaken France, they appear to have considered the maintenance of her integrity essential to the equilibrium of the Commonwealth of Europe.

Disposition of the French.

In the situation of the French, various circumstances are in favour of continued Peace. The ship-owners, insurers, and other classes, who in this Country derive great temporary advantage from a state of War, are of very little account in France: the same holds in regard to the monied interest, the merchants and traders generally; all of these are on a footing much inferior to that which the same classes now hold in England, or held in Holland in the day of her prosperity. The great majority of the French are agriculturists, and a state of War can hold out little prospect of rise of price to the farmers of a Country which imports very little, because in nine years out of ten its produce is equal to its consumption. When to all these inducements to Peace we add, that the levies for the French army are still made by that most odious law, the Conscription, a law which, operating by ballot, keeps parents in continual uneasiness, and takes young men from their homes at a time at which they ought to enter on employments for life, we shall have little difficulty in believing that a renewal of War would be extremely repugnant to national feeling in France. It is, we believe, equally repugnant to the views of the reigning Sovereign, who cannot but be aware, that with the great political divisions now existing in France, and which are likely to continue during the present generation, a contest with this Country would be replete with danger to his sway.

Colonies no longer a cause of War.

Another fertile source of War during the last century, the desire of possessing Colonies, has also ceased; Mexico, Peru, Chili, Brazil, are now open to every flag, and not likely to become a cause of War between the Powers of Europe. We have learned to our cost, how greatly they were overrated, and that Ages must elapse ere they become really valuable. And those among us, who, dazzled by the increase of money incomes during the late contests, consider a state of War conducive to national wealth, will do well to bear in mind the distressing reaction of the last eighteen years. The War, it is true, added largely to the income of our agriculturists, merchants, and manufacturers, but have we not, in almost every year since 1814, witnessed the successive disappearance of those splendid additions? Their foundation was temporary; resting on high prices and the demand of Government for men and money, they ceased together with their cause; involving many classes of the community in all the evils of a transition from affluence to poverty, from hope to despondency. The more enlightened part of the nation has now become aware of the temporary nature of such gains and of the immense loss attendant on such reactions. Our public men may therefore be assured of its support in that pacific course, by which alone they can hope to heal the wounds of Ireland, or lighten the burdens of England.

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Effect of continued Peace on our trade.

Assuming it, therefore, as probable, that a state of Peace will be maintained for a considerable time, we proceed to the interesting, it may be almost said, the anxious question, how far, the reduced rate of prices attendant on Peace, will affect the state of our trade. The first point is to ascertain to what extent our produce and manufactures have undergone reduction in price, and in this we shall be aided by the returns of our Custom-house.

Official value explained.

There is, as is well known, a double registry of our exports in the Custom-house books; one founded on the market price, or the value as declared by the exporting merchants; the other a record of quantity rather than of price, the value affixed to each kind of goods being the same year after year, and taken from an official list or standard fixed so far back as 1696. In this standard certain articles, such as woollens, linens, cottons, are computed at so much by the yard or piece; while others, such as hardware, leather, soap, are reckoned by weight. The result of this calculation is then entered in the Custom-house Ledger, and as details of quantity would be uninteresting to the Public, the rule at the Custom-house is to print nothing relative to weight or dimensions, but to give the result in money, and in the shortest form, *viz.* in one line for each year; thus,

British Produce and Manufactures exported in the following Years, calculating first the quantities and afterwards their amount in Money, according to the official standard of 1696.

WAR.		PEACE.	
1810	£45,869,859	1826	£40,965,736
1811	32,809,671	1827	52,219,280
1812	43,243,173	1828	52,797,455
Total of three years of War	121,922,703	Total of three years of Peace	145,982,471
Annual average	40,640,901	Annual average	48,660,823

Exports greater in quantity

These sums being merely an index of quantity, it follows, that in that respect, there is, since the Peace, an increase of more than 20 per cent. in our exports; but in their value the result is very different.

Value, or Market Price of the abovementioned exports, as declared in the respective years, by the exporting Merchants.

WAR.		PEACE.	
1810	£49,975,634	1826	£31,536,723
1811	34,917,281	1827	37,182,857
1812	43,657,864	1828	36,814,176
Total	128,550,779	Total	105,533,756
Annual average	42,850,259	Annual average	35,177,918

but less in value.

This return exhibits, in the first instance, a decrease in the money value of our exports since the latter years of the War, of nearly 30 per cent. And as we have seen that our exports in late years are greater in quantity than during the War by 20 per cent., it follows that the total decrease, in the money value of British produce and manufactures exported, is nearly 50 per cent. compared to our prices twenty years ago; that is, when foreigners pay for our goods in money, we receive only £50 for articles which twenty years ago produced £100; a formidable reduction truly, but fortunately little more than nominal, since the articles supplied by foreigners in return, such as wool, cotton, silk, lead, have fallen in an equal, or nearly an equal proportion.

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It may be interesting to our readers to mark the steps in this progressive decline of prices; and for this purpose we shall select by far the most important article in our list of exports,—our cottons. In the year 1814, the market price of our cottons was nearly the same as the rate at which they are valued in the Custom-house ledger; that is, a given quantity of cotton goods, amounting, by the official standard of valuation, to £100, might have been bought in the market for £104. Observe how constantly, and even rapidly, the market price has declined since that time.

Decrease in the price of cottons.

Cotton Goods exported.

Years.	Valuation by the Custom-house Rates.	Market Price.
1814	£100	£104
1815	100	90
1816	100	80
1817	100	70
1818	100	77
1819	100	72
1820	100	67
1821	100	64
1822	100	59
1823	100	56
1824	100	56
1825	100	57
1826	100	49
1827	100	47
1828	100	46

We find here a decline, and to a considerable amount, in every year, except in the two seasons of excitement, 1818 and 1825. In other articles, the fall of price has not been altogether so great as in cottons; thus

Manufactures exported; comparative value of the same quantity at different periods; viz. in 1814 and 1828.

Of other goods.

	Market Price in 1814.	Market Price in 1828.	Average Annual Amount exported in late years, as declared by the Merchants.
Hardware	£100	£66	£1,300,000
Woollens	100	60	5,000,000
Linen	100	58	2,000,000
Silk	100	48	800,000
Cotton	100	44	14,000,000
Leather alone has nearly maintained its price	100	98	300,000

This fall of price, however, is a loss only in some respects; for if we inquire into the manner in which it has taken place, or under what heads of charge it ought to be appropriated, we shall find it to have arisen from.

A reduced price of wool, cotton, silk, and other raw materials;

The manner of such decrease.

A reduction of wages to the workmen, and of profit to their employers;

Improvement of the machinery employed, and a consequent cheapening of manufacture from that, as well as from the greater subdivision of the work.

As to the first of these heads, the supply of raw materials continues abundant even at low prices. Cotton has declined ever since the Peace, yet the import increases, though the price is now only half of what was, some time since, accounted the lowest cost of its production. Of wool, the import from the North of Germany alone is now much greater than it formerly was from all foreign Countries together; and of silk, our Indian territory offers a progressively increasing supply. Such are the consequences of improved modes of cultivation, and of the application to commercial objects of the vast amount of labour and capital formerly absorbed by War.

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Reduction of price from such a cause, or from improvements in machinery, is evidently a public benefit; but a decrease in the wages of workmen, or in the profits of their employers, is very different, and has, from its long duration, given rise to much distress. Relief is to be looked for, not from increase of income to either the employers or their workmen, such being altogether unlikely in this season of profound Peace, but from a reduction of expense; a fall, as Adam Smith would have termed it, in the cost of food, clothing, and lodging. This reduction has already taken place to a considerable extent: the decline in the average price of wheat in this Country since the Peace having been in the proportion of three to two; (from 90*s.* to 60*s.* a quarter;) a fall so great as to have caused the gradual disappearance of most of the capital accumulated by farmers during the War, and to have produced a heavy deduction from the property of landlords. In what manner has this great change affected our manufacturers and traders? In one sense it has been advantageous, in another the reverse; it has lessened to them greatly the expense of subsistence, but it has considerably narrowed the consumption of manufactures and merchandise by our now impoverished agriculturists. The latter are in the present year (1832) in the same depressed state as ten years ago, and will do well to limit their expectation of relief to two points: the probable fall in the rate of the interest of money; and a further reduction in farming charges; in a return, in short, to the scale of 1792.

Reduced price of corn: its effect on trade.

Many of our landlords and farmers are, as is well known, largely indebted for money borrowed on mortgage and other security. The Committee on the state of agriculture in 1821, aware that such engagements were of great extent, and that in time of Peace repayment of the principal was not to be expected, confined its attention to the prospect of the agriculturists paying the yearly interest, and enlarged on the abundance of monied capital as likely to lead to a reduced charge for its use. The authors of that Report judged soundly, so far as regarded our political prospects; they knew the anxiety of our public men to maintain Peace, and inferred from the state of France, that it was very unlikely that the Government of that Country would for a long time incur the hazard of War. The rate of interest declined, and borrowers obtained an abatement in general from five to four per cent.; but in a few years it rose again, in consequence of the infatuation of our Countrymen, on the opening of Spanish America. The sums so imprudently advanced to that Country in loans and mining speculations, or paid to foreigners for our imports in 1825, exceeded all anticipation; and in conjunction with political disquietude, have ever since kept our surplus of disposable capital within narrow limits. But for some time back, circumstances have been indicative of its renewed abundance, and as it is very unlikely that our merchants will repeat the imprudence of sending large sums abroad, the agriculturists may entertain a hope of the return of the advantages of 1822, without the reaction which was then incurred by entering on a new and unknown field.

Having now completed the Historical notice of our

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trade, we proceed to give an account of its present state; beginning with our Manufactures, a subject of sufficient interest to claim a minute and copious exposition.

MANUFACTURES OF ENGLAND; THEIR PROGRESS AND PRESENT STATE.

Woollens.

The woollen manufacture; its early state.

We begin our sketch of the National Manufactures with the Woollen trade, as well on account of its importance as because wool was the chief article of export from England in early times. It continued to be so for several centuries after the Norman Conquest, and was the result of two causes; the great extent of our pastures, and the inability of our population to manufacture into cloth the quantity of wool annually produced. Our pastures are superior to those of France, Germany, or Poland, because in England rain is of more frequent occurrence, and droughts are comparatively rare; while on the Continent, at least in many inland parts, the grass becomes dry and parched during the Summer months. As to the state of our population, during the Middle Ages it was almost all resident in cottages; in other words, our agriculture was so rude and the personal exertion of the husbandman was so little aided by machinery or suitable implements, that the labour of no less than four persons in five was needed in the fields to provide the subsistence required by the community at large. Of the smallness of our towns an estimate may be formed from the following Table.

Population of England in 1377.

Population of the Chief Towns in England from a Census in 1377.

London	35,000
York	11,000
Bristol	9,000
Plymouth	7,000
Coventry	7,000
Norwich	6,000
Lincoln	5,000
Sarum, Wiltshire	5,000
Lynn	5,000
Colchester	4,500
Canterbury	4,000
Beverley	4,000
Newcastle on Tyne	4,000
Oxford	3,500
Bury, Suffolk	3,500
Gloucester, Leicester, Shrewsbury, each somewhat more than	3,000

Such was the limited population of our towns in the XIVth Century: in the XIIth and XIIIth it was still smaller, while Flanders could boast of considerable cities in Bruges, Ghent, Antwerp, and Brussels. Hence the superiority of the Flemings in weaving as in other Arts: their looms were better, their workmen were more expert, their employment was more subdivided; there was, in short, a more ready supply in their towns of all things auxiliary to a complicated process of manufacture. English weavers, residing in hamlets or villages, and indifferently provided with the requisites for manufacture, could prepare only coarse cloths; the finer were made in the Netherlands, and sent to England and France for sale. The money thus obtained by the Flemings for the cloths made of our wool supplied them with a fund for the purchase of further quantities of the raw material. Such was the routine of sale and purchase between the two Countries during several centuries, but our Countrymen became in time desirous of extending their share of the manufacture. Accordingly, in the middle of the XIVth Century, (in the active reign of Edward III.,) weavers from Ghent were invited to settle in England and to introduce the art of making the finer woollens. They were established at first in villages in Kent and Essex, not far from London; not that the spots in question had any marked advantage as to fuel or water-power, the great considerations in the present Age; but on account of their vicinity to conveniences of another kind, as by the Thames they could communicate on one side with London, on the other with the Continent.

The inland Counties would not in that early Age have been suitable for such establishments, being devoid not only of canals but of roads, and presenting neither opportunity of sale nor facilities for manufacture. But in course of time those Counties became greatly improved, and the woollen manufacture extended to the more remote parts of the Kingdom; first to Gloucestershire, where labour and fuel were cheap and wool was to be purchased at the first hand; and eventually to the West Riding of Yorkshire, where to all these advantages was added the convenience of waterfalls for moving machinery.

Slow progress of this manufacture.

The extension of the woollen manufacture of England has been very gradual, because it was long carried on by insulated workmen, and received little aid from the mechanical discoveries and inventions which have caused so rapid an increase in cotton-works. Another cause of its slow increase in former times, was that the sale of the fabric was long confined to the home-market. France, Germany, and Belgium made woollens for themselves; it was not till after 1700 that the export of English cloth to Portugal and Holland became considerable, or that our North American and West Indian colonies acquired so large a population as to render them customers of importance. At the time in question, (1700,) the value of our woollens sold for home-consumption was computed not to exceed five or six millions sterling; that of our exports was between two and three millions; in all eight millions. In the course of the hundred years that followed, the quantity made for the home as for the foreign market appears to have nearly doubled, and to have formed, in 1800, a total value of about seventeen millions. At present, (1832,) the value of our woollens exported continues nearly as thirty years ago, about five millions yearly, but that of our home-consumption may be computed at seventeen or eighteen millions, making a total yearly value of twenty-two millions or upwards, the quantity consumed at home having naturally increased in proportion to our population.

Value annually made in England.

Price of our woollens.

Next as to the price of our woollen cloths at different periods of our History, the fluctuations have been less than is commonly imagined. In fact, if we pass over the temporary enhancement which in this, as in almost every article, prevailed during the Wars of the French Revolution, we shall find the money price of woollens to have been nearly uniform for more than a century and a half. Of this we have the means of judging by comparing the present prices with what is termed the official value, or scale of prices adopted in the year 1696, for the purpose of computing the value of our exports. So

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great has been the fall in the cost of wool and woollen cloth since 1815, that at present (in 1832) the price of either in money is lower than it was a hundred and forty years ago; it must be admitted, on the other hand, that the cloth is lighter and less durable. The wages of the weavers and other workmen are higher, but that additional expense is balanced by the greater aid we now derive from machinery, and the saving in the consumption of wool. The French have not yet made an equal reduction in the quantity of the raw material; they use considerably more than our weavers in a given length of cloth, and their woollens consequently are both thicker and heavier.

Exports to America.

The United States of America were long the chief foreign market for our woollens, and as their population was in a state of rapid increase, they purchased more after their separation from us in 1783 than at the time they were our colonies. The first blow given to this great branch of our exports, was by an act of our own Government; by the Orders in Council of 1807, which, by stopping the foreign trade of the Americans, deprived them of the means of purchasing and obliged them to manufacture for themselves. Establishments were accordingly formed for that purpose in the United States, and a large amount of capital was invested in them, after which it became in a manner obligatory on their Government to support them. That could be done only by imposing heavy duties on foreign woollens, particularly those of England; duties which formed a feature unfortunately too prominent in the American tariff of 1828, and which are still persisted in to the incalculable injury of both Countries.

Seats of the woollen manufacture in England.

Next as to the chief seats of this manufacture in England, and the number of persons employed on it. Though the value of the woollens made annually is not nearly equal to that of our cottons, the number of persons employed in the former is greater, because machinery is less used. The mechanical improvements of the past and present Age have been applied in the first instance to cottons; to woollens later and less extensively. As to the ports for the export of woollens, London was long the principal, but Liverpool has taken the lead in that respect since the extension of canal navigation and the great increase of the comparatively neighbouring towns of Leeds, Halifax, and Wakefield. The West Riding of Yorkshire, which, half a century ago, was supposed to supply a third of the woollens made in England, may now be considered as furnishing fully the half. Wiltshire, Gloucestershire, and Somersetshire, the other seats of this manufacture, have been nearly stationary; that is, without decreasing their respective quantities, they have had but little share in the great augmentation which has taken place during the last fifty years.

Supply of wool.

As to the supply of the raw material at home, the last century has witnessed a great increase in the productiveness of our pastures, in the size of our sheep, and, consequently, in the weight of the fleeces. None of these, however, have advanced in an equal degree with our population, with the number of the buyers and wearers of our cloths; so that notwithstanding all the improvements in the mode of preparing wool, and the reduced weight that now suffices for the same extent of cloth, a great increase has taken place in the import of the raw material. In former times, the only wool brought to England in large quantities was from Spain, a Country possessing in its mountains and valleys a great variety of climate and pasture grounds: the finer qualities of Spanish wool were useful, and indeed requisite for mixture with our own growth. About the year 1700, the import of Spanish wool averaged about one million pounds annually; it increased steadily, but slowly, till towards the year 1775, when a rise in the price of English wool and an extension of the manufacture caused a continued increase of import, so that about 1800, the Spanish wool annually brought to this Country weighed about four million pounds. It has continued in some degree to increase, and may be said to have reached for some time back six million pounds a year; a large quantity certainly, but bearing no proportion to the surprising augmentation of our import from Germany. That Country, formerly of so little account in the supply of wool, now annually sends us from twenty to twenty-five million pounds weight, so greatly has the management of its flocks improved in the present Age, particularly in Saxony. Altogether the foreign wool imported into England at present is about thirty million pounds a year. Our home-growth being subject to no duty or official inspection, its amount can only be guessed at from the number of our sheep, and the average weight of their fleeces. If, as has been computed, the growth of wool in Great Britain and Ireland be so much as one hundred and fifty million pounds, the total of the wool used in our manufactures is about one hundred and eighty million pounds weight a year, its value about £12,000,000 sterling.

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Import of foreign wool.

From Spain.

From Germany.

The export of English wool, long strictly prohibited, has been free since 1825; it averages at present about three million pounds, and is made chiefly to France and the Netherlands.

New South Wales and Van Diemen's Land now send us a yearly supply of wool, in quantity about two million pounds; the quality remarkably good. It is exempt from duty, while our imports from Germany, Spain, and other foreign Countries, are subject to a duty of a halfpenny or penny per pound, according to their quality.

Linens.

Linen

We come next to a manufacture of as ancient, or nearly as ancient date in England as woollens, but of inferior importance in a national view. Though our climate is as favourable to the growth of flax and hemp as that of the Countries in which these products have been most cultivated, such as Flanders, Germany, or Livonia, linen has not at any time ranked among our principal manufactures. If of the common qualities enough for home-consumption has been prepared in England, the finer qualities have, in general, been imported; in former times from the Netherlands, but for a century and upwards from the North of Ireland. Into Ireland, the cultivation of flax and weaving of linen were introduced on a large scale above one hundred and fifty years ago, and have ever since been patronised by Government. Liberal bounties were long paid on the export of linen, and what was of far more importance than a bounty, the consumption of England, as regarded the finer qualities, was supplied by the Irish manufacturers. The quantity of linen imported from Ireland to England during the last forty years has annually amounted to thirty, forty, and forty-five millions of yards, a part of which was re-exported, but a far greater part retained and consumed at home. The average value of this yearly supply from Ireland amounts, even at the reduced prices of late years, to two millions sterling.

In Ireland.

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In Scotland.

In Scotland, the manufacture of linen has, in general, been confined to the coarser qualities. On these, also, a large bounty on exportation was given during nearly a century that they might be enabled to maintain in America and other foreign Countries, a competition with the linens of Silesia and other parts of Germany, which had taken a lead in the market, being both good in quality and moderate in price. Bounties, it is now admitted, are, in nine cases out of ten, impolitic, and it had, perhaps, been better to have left our linen, like our cotton manufacture, to its natural course; the effect, however, of the aid from Government has been to establish linen-weaving on a very large scale in Great Britain as in Ireland, so that now that all bounty on linen is withdrawn, our Countrymen can continue the competition with the advantage of improved machinery, of workmen long practised in their tasks, and of large sums of capital invested in the business.

Principal seats in England.

In England, the chief seats of the linen manufacture are at Leeds and Barnsley in Yorkshire, and in towns of less extent in Lancashire and Cumberland. In Scotland, they are in the Eastern Counties, at Dundee, Arbroath, and Montrose. In Ireland, the seat of the linen manufacture is in the North, and the weavers live generally in detached cottages; but at Leeds and in Scotland, the business has for a considerable time been carried on in factories or collective establishments for account of mercantile houses. The latter having the command of capital, a subdivision of employment, and the various other advantages of extensive cooperation, seem likely to prove, or rather have already proved, an overmatch for the cottage system; so that Ireland can scarcely hope, under present circumstances, to increase her products, particularly in the more common qualities.

Annual value.

The increase in the quantity of our linen annually manufactured has not been by any means in proportion to our population, on account of the surprising extension of our cotton manufacture during the last fifty years. The total value of the linen made annually in Great Britain and Ireland is at present about twelve millions sterling, of which two millions are sent abroad; the coarser sorts going to the West Indies for Negro clothing. As to the raw materials, both flax and hemp are considered by agriculturists as exhausting crops; they are, consequently, much fitter objects of cultivation in Countries like Prussia, Courland, or Livonia, where population is thin and corn low priced, than in England, where the farmers find consumers of corn in abundance almost at their doors. Our imports accordingly have long been on a great scale; of late years they have amounted to about twenty thousand tons of hemp and forty thousand tons of flax, three-fourths of both being from St. Petersburg, Riga, Revel, and other Russian ports in the Baltic and Gulf of Finland.

The Cotton Manufacture.

The history of the cotton manufacture in England differs materially from that of the woollen or linen: its introduction was much later; its extension has been far more rapid. Indeed, the progress of the cotton manufacture in England during the last sixty or seventy years is the most remarkable event in the history of our productive industry. About the year 1700, the total import of the raw material did not exceed five thousand bags or bales; during many years its increase was slow, but in the early part of the reign of George III. the invention of carding machines and spinning jennies greatly extended the manufacture, so that in 1775, our average import of cotton became nearly 18,000 bales.

By the end of the next twenty years, *viz.*

in 1796, it averaged 100,000 bales or bags;
in 1801 .... above 150,000
in 1806 .... above 200,000
in 1810 and 1811 above 300,000
in 1816 .... above 370,000

since which date it has continued to increase every year, and at present (1832) exceeds the surprising number of 800,000 bales, the average weight of which is not less than three hundred pounds each.

The weaving of cotton first practised in India.

As the cotton plant requires a great degree of heat to bring it to maturity, and India was one of the Tropical Countries which was peopled at a remote date, we may consider it to have been one of the earliest seats of the cotton manufacture. It certainly has been so since the earliest records in authentic History, for cotton cloths appear to have formed an article of export from India to Europe at the time that the Indian trade was carried on by way of the Red Sea and Thebes in Upper Egypt. The lightness of these cloths made them easy of transport, while the low wages of workmen in India prevented attempts in Europe to rival this manufacture during many Ages, in short until the towns of modern Italy acquired considerable population. Even their efforts hardly deserved the name of rivalship, so superior were the fabrics of the Hindús; and it was not until half a century ago that the improved machinery of Great Britain enabled our workmen to balance the cheap labour of the East.

Progress of the manufacture in England.

We read in printed works of cotton manufactures at Manchester, so long as two centuries ago; but these were cottons only in name, the raw material being wholly wool, and the name of cotton given to the cloth from its resemblance to the cottons made in India and Italy. Wool ceased to be used in this manufacture seventy years ago, but even then the process of preparing this article for a market was very primitive. The cotton weavers in Lancashire, like the linen weavers in the North of Ireland, lived in detached cottages, and were in the habit of going to market in the neighbouring town, first to purchase thread, afterwards with the finished web for sale. They thus received very little aid from shopkeepers or dealers in towns during the time the weaving was in progress. But about the year 1760, the Manchester dealers, finding the demand for cottons increase, came forward to assist the weavers so far as to supply them with thread, or if they preferred it, with raw cotton to be spun into thread by the weaver's family; engaging at the same time to be the purchasers of the webs at a given price. The workmen were thus considerably relieved, being assured of a market for all or almost all the cloth they could get ready; but spinning by hand being necessarily tedious, the quantity of cottons made continued to be very limited. At last, in 1767, an ingenious person, named Hargraves, invented the spinning jenny, a machine which from the first enabled one person to spin eight threads with the same ease as one, and which was eventually so simplified and improved as to enable a boy or girl to work above one hundred spindles.

Mechanical inventions.

This machine, however, was fit only for spinning the weft or cross threads of a web, and had not the power of giving the firmness or hardness required in the warps

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or running threads; but that great desideratum was soon after supplied by the "spinning frame," the invention of Mr. (afterwards Sir Richard) Arkwright, which spins a vast number of threads of any degree of fineness and hardness; leaving it to the person in attendance only to supply the machine with cotton, and to join the threads when they happen to break. For this most important improvement a patent was given to Arkwright; its exclusive use during the period of the patent laid the foundation of the vast fortune of his family; and on its expiring in 1785, its general adoption greatly extended the cotton manufacture throughout the Kingdom.

Arkwright's discoveries.

One of the next improvements of consequence was the introduction of the mule jenny, a compound of the spinning jenny and spinning frame. All these inventions related to spinning, and surprisingly extended the quantity of yarn. The object then in request was machinery for weaving, and that was sometime after supplied by the most remarkable of all these inventions, the power loom, or substitution of mechanical for manual labour in weaving. Power looms during the last fifteen years have been multiplied to almost incredible numbers: they have, it is true, caused a serious reduction in the wages of weavers, and, consequently, a great deal of individual distress, but, in a public view, they have been highly advantageous. Without them, it would not have been practicable to have increased so rapidly as we have done the quantity of cottons made in this Country, or to have competed so successfully with the lower wages of foreigners.

The power loom.

Import of cotton wool.

Cotton in former times was imported from the Levant, chiefly from Smyrna; afterwards from our West Indian colonies, but from these the supply has been all along limited. Carolina and Georgia did not begin the cultivation of cotton until a recent date, *viz.* after 1790, but it has since been extended in these States in a surprising degree. Of late years, the South Western States, New Orleans, and Alabama, have greatly increased their cotton cultivation, so that the total yearly export from the United States of America now exceeds eight hundred thousand bags of about three hundred pounds each, of which above five hundred thousand bags are sent to England. Next in the supply of cotton come Brazil, the East Indies, and, during the last ten years, Egypt.

Quantity manufactured.

It is usual to compare the extent of manufacture in one year with that in another by the number of bags consumed or wrought up weekly by our manufacturers. In the year 1824, the number of bags so wrought up was about 10,000 a week; in 1827, it had increased to more than 12,000; and it now exceeds 16,000 a week! Comparing these quantities with the consumption of the years 1816 and 1817, we find that the quantity of cottons manufactured in Great Britain has more than doubled in the course of twenty years; but so great has been the reduction in the cost of the article that the money value of the vast quantity now annually made (between thirty and thirty-five millions sterling) is not much above that of the far smaller quantity prepared in 1817.

Decline of price; its causes.

This great fall of price has been owing to several causes; partly to the reduced cost of the raw material, and successive improvements in machinery. The decline in cost of the raw material has been so great that the pound of cotton yarn which in 1814 cost one shilling and sixpence, is now supplied at seven-pence or eight-pence. In all our manufactures there has been a large increase in quantity and decline in price since the Peace; but the difference is greatest by far in cotton. In woollens, silk, leather, and other articles, the increase in the quantity annually made since the Peace has borne a proportion to the increase in our population, *viz.* about thirty per cent.; but in cotton the increase has exceeded one hundred per cent., so greatly is the use of cottons extended in this Country, South America, and India.

Another remarkable feature in our cotton trade is the magnitude of the export compared to our home-consumption. Of the woollens made in Britain the proportion sent abroad is a fifth or sixth; of our hardware the proportion is somewhat more; but of cottons it is fully half. The reason is that they are sent not to a few particular Countries, but to all parts of the World. Taking the number 40 as the integer of our exports of cotton and cotton yarn, the proportions of the different Countries will be as follows:

Countries to which we export cottons and cotton-yarn.

West Indies	5
Brazil	5
Spanish America	4
United States and British North America	4
East Indies	$4\frac{1}{2}$
Africa	1
The Levant	$1\frac{1}{2}$
Germany	4
Italy	$3\frac{1}{2}$
Portugal	$2\frac{1}{2}$
Spain	2
Netherlands	1
Other parts	2
	40

Germany and most parts of the Continent of Europe manufacture such articles as woollens, leather, linen, hardware, to the extent of nearly the whole of their consumption, because manufactures in those branches were established in the respective Countries several centuries ago, in times when England had no marked superiority over her neighbours. But cottons came into demand at a time when our productive industry was in an advanced stage, when our capital had become large, our towns populous, our machinery powerful, and fuel abundant and cheap in almost all our towns, from the extent of our canals.

These are the causes of the success of manufactures, and in these the different Countries of the Continent, even the Netherlands and North of Italy, whose population is dense, and their wealth of old date, are greatly inferior to England: hence the far greater extension of the cotton manufacture in this Country.

Cotton manufactures abroad.

The cotton manufactures of France were very considerably extended about twenty years ago. Labour in that Country is still somewhat cheaper than here, but fuel is dearer and the machinery less complete. The amount of cottons annually made by the French is consequently stationary, and forms not quite a third of that which is prepared in Britain; nor are they likely to gain on us in the race of competition, for they cannot supply foreign markets at equally low prices. The same reasoning holds in regard to the cottons of the Netherlands, Germany, and Swisserland: in all those Countries establishments were commenced with alacrity during the War, and in all it is now found very difficult to withstand English competition even when our goods are subjected to an import duty. The dearness of provisions in England during the late Wars, and the high rate of wages, were the main grounds of the expected success of foreigners; but these

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disadvantages have gradually given way, particularly since 1827, when our Corn laws were modified, and the cost of provisions in England was brought so much nearer to that of other Countries.

Increased population of English Cotton manufacturing districts.

The consequence has been a continued increase in the population of the cotton manufacturing districts. According to the last census, that of 1831, the number of inhabitants in the chief towns was as follows:

Manchester and Stockport	178,000
Bolton (Great and Little).....	40,000
Oldham	32,000
Blackburn	27,000
Wigan	21,000
Bury	15,000
Warrington................	16,000
Preston	33,000
Glasgow and suburbs........	202,000
Paisley	60,000

In most of these places the increase of numbers during the last seventy years has been in the remarkable proportion of nearly four to one! Glasgow has an extensive and varied trade distinct from the cotton manufacture, but in all the other towns the cotton trade, in one shape or other, is the main spring of local activity. The total number of persons employed in it is not ascertained, but amounting probably to 400,000, would be far greater, did not machinery perform so much of the work in every stage. To conclude, this branch of our productive industry has more than any other enabled us to bear the unparalleled burdens of the times; and it happily promises to continue to be one of the pillars of our National wealth; no other Country, whether in Europe, America, or India, possessing advantages for conducting it to be compared to those of Great Britain.

Iron and Hardware.

Early state of the manufacture of iron.

Of all our great branches of manufacture, that of iron has been, next to cotton, the most remarkable in its increase. Iron-ore was known to exist in different parts of England several centuries ago, and began to be smelted in a few situations, such as the Forest of Dean in Gloucestershire, where wood fuel was abundant and in the vicinity of the mines. The demand for iron increasing, the consumption of the wood became so considerable, as to induce the cautious Ministers of Queen Elizabeth to restrain it by Act of Parliament. The great desideratum now was to discover whether coal could be made to answer the purpose of wood fuel in smelting iron, and so early as the year 1619 a patent was granted for the use of coal for that purpose. But a very long time elapsed ere the existing prejudices and obstacles to the use of coal were removed. The works of the first patentee for coal were destroyed by assemblages of the people, who had been formerly employed in cutting and carrying wood fuel; and other iron-masters were deterred from following his example. The process of smelting by coal thus remained in a rude state, and there prevailed a general belief that iron so smelted was of far inferior quality to that which was prepared by wood or charcoal. But as the demand for iron increased with our population during the XVIIth and XVIIIth Centuries, the consumption of wood became so alarming as to cause a multiplicity of complaints from the inhabitants of the districts adjoining the mines. Fortunately by that time an increased familiarity with the use of coal had improved our workmen in the method of applying it to smelting, so that the use of it for that purpose extended itself considerably after the middle of the last century.

Its surprising increase.

Seventy years ago our mechanics and hardware manufacturers chiefly made use of Swedish iron, and the quantity of English iron prepared did not exceed 20,000 tons a year: it soon, however, experienced a great increase, for our furnaces had were so increased that the iron made at them amounted

in 1788 to 68,000 tons,
1796 to 125,000
1806 to 250,000
1820 to 400,000
while at present (1832) it
is computed at nearly . 700,000

This vast quantity is made in the following parts of the Country:

Scotland, chiefly at the Carron works	40,000 tons.
Yorkshire and Derbyshire	65,000
Shropshire	80,000
North Wales	25,000
Glamorganshire and Monmouthshire	270,000
Staffordshire	220,000

Decline in price.

It thus appears that the quantity of iron annually made in this Country has tripled in the course of twenty years. This increase has, perhaps, been too rapid, for the present prices are not sufficient to indemnify the iron masters, or to enable them to pay sufficient wages to their workmen. A partial reduction of the number of furnaces has consequently taken place, but notwithstanding the present depression, no branch of our productive industry is more likely to recover, for none rests on more solid foundations. All our iron mines are situated in the vicinity of coal, and most of them have the advantage of a direct import of provisions from Ireland; in other words they are in the neighbourhood of cheap materials and cheap labour. In the transport of so heavy an article as iron, canals and railways are of first-rate importance, giving our iron-works an advantage not possessed by one in ten of those on the Continent. It may fairly be assumed that of no article is the use more likely to extend as Society augments its numbers, or improves its habits and institutions. In England iron is in progress of substitution for timber in various respects; abroad there must ere long be an end, particularly in France, to that impolitic system of high duties on English iron which go far to deprive the French Public of a most useful material. Add to this the probability, in this Age of invention and discovery, of further improvements in the mode of smelting, or otherwise preparing iron; comparatively recent as the manufacture is in this Country, and unfettered as it is likely to remain in respect to duty or excise regulations, which have so often proved an obstacle to useful experiments and amended processes.

Of the total of the iron annually made in this Country about a sixth part, or one hundred and twenty thousand tons, are exported; and the cheapness of freight in time of Peace is in favour of an increase of our exports.

Pig iron and wrought iron explained.

The name of cast or pig iron is given to the metal when first extracted from the ore: wrought or soft iron is pig iron refined, or rendered malleable. This process takes place in more than two-thirds of the iron annually made, after which it is formed into bars, bolts, rods, &c. for sale. The exports take place chiefly in wrought iron, because it is fit for immediate use by the

Commerce. Mechanic, but the prices stated at the iron-works, or in the public papers, apply to pig iron. In years of brisk trade, such as 1824 and 1825, these prices were so high as £10 or £12 a ton; at present they are not half so much; so that vast as is the quantity (700,000 tons) made annually, the value does not exceed £4,000,000, to which £1,000,000 or £1,500,000 may be added for the cost of forming pig into wrought iron.

Hardware. Such is the value of the whole of the iron or raw material prepared annually in Great Britain; but the hardware, or articles manufactured from iron, amount, in consequence of the labour bestowed on them, to nearly twice that sum. These articles are very various in their kind, and are made in surprising quantities: they comprise knives, scissors, razors, and all kinds of cutlery; fire-arms, swords, sabres, locks, bolts, bars, &c. In addition, hardware comprises a variety of articles made of tin, brass, copper, steel; in short, the almost endless list of goods which afford employment to the inhabitants of Birmingham, Sheffield, and the populous towns in their vicinity. In hardware, as in cotton, there has been, since the Peace, a very great increase in quantity accompanied by a heavy and general decline in price. As to the value of the iron and hardware of all kinds made in Great Britain at present, (1832,) the computed amount is £17,000,000 sterling, of which about £4,000,000, nearly a fourth part, is sent abroad. The chief foreign markets are the United States of America, Canada, India, and the West Indies.

Though this, like other branches of manufacture, has been for some time in a very depressed state, there is, happily, the strongest reason to anticipate a revival of its prosperity. The abundance of our coal and the cheap rate at which both it and iron are conveyed by canals, are of the greatest importance to this branch of our industry, and have, indeed, been the chief causes of its extension. To these are now to be added the advantages arising from the division and subdivision of employment in towns of so great extent as Birmingham and Sheffield, where the capital vested in trade is ample, and the machinery and tools used by the manufacturers are greatly superior to those of the Continent. In no other Country can hardware articles of equal quality be supplied at so cheap a rate. We are therefore justified in expecting a great eventual increase in the sale of our iron and hardware both at home and abroad. At home, iron is likely to be used more and more in public works, such as railways, or in roofs, pillars, beams, canal boats, as a substitute for timber. Abroad, particularly in France, the use of iron and hardware articles cannot fail to receive a great extension as soon as a reduction takes place, in the exorbitant and impolitic import duties. Those duties were intended to protect the iron-works of France, but the attempt is found to be unavailing; most of those works labouring, from insufficiency of fuel, under so serious a disadvantage that the Government of France would act wisely in making a pecuniary sacrifice towards indemnifying the owners, rather than continue to deprive its subjects of the various advantages that would result from the cheapness of an article of such first-rate importance as iron.

The Leather Manufacture.

Leather. This department of our productive industry is on a footing considerably different from that of our cotton or hardware. The chief consumption of it is at home, and the export is comparatively small, because in this manufacture we do not possess any marked advantage over our Continental rivals. First, as to the supply of the raw material; the number of cattle in Great Britain and Ireland, computed at present between six and seven millions, is a great addition to the number half a century ago, while the weight of the animals, and consequently the size and weight of their hides, has increased surprisingly; but in neither is the augmentation proportioned to the increase in the consumption of leather, which, like our population, has more than doubled since the year 1780. We are consequently obliged to import annually a large quantity of hides, partly from Lithuania and other Provinces of Russia, where cattle run wild in the forests, but more from Paraguay, where among the immense herds that range the uncultivated tracts, thousands and tens of thousands of cattle are killed merely for the sake of their hides. Unfortunately, the troubled politics of that and other parts of South America for many years past, have limited the supply of hides and have kept up the cost of leather so highly that of all our manufactures it has experienced the least decrease of price since the Peace. It has been a matter of complaint that the repeal of the leather tax should have produced hardly any abatement in the price of shoes; but we must not imagine that the repeal was unavailing, for it prevented the rise which would otherwise have followed our annually increasing consumption.

The vast quantity of hides supplied by the slaughter of cattle in London are tanned chiefly in Bermondsey in Southwark, the seat of the largest tanneries in the World. There are also very extensive similar establishments in Lancashire, Staffordshire, and other Counties, in which the towns are populous and the carriage of hides from one part to another is facilitated by canals. In the further process of the manufacture, we mean making the leather into harness, saddlery, boots, shoes, &c., which is almost altogether carried on by manual labour, little advantage is derived from our national superiority in fuel and machinery. In France, leather is considerably cheaper than in England, but both its quality and the workmanship of the different articles made from it, are decidedly inferior. The total quantity of leather tanned and otherwise prepared in England is about 25,000 tons; the number of persons employed in the various branches of the manufacture about 250,000; and the value of all the articles made is about £15,000,000 a year, of which shoes alone form the half or upwards.

Gloves. The making of gloves was carried on with considerable profit during our Wars with France, but received a serious check from the suspension, in 1812, of our trade with the United States of America, which were the chief foreign market for the article. Unfortunately the depression has continued in a greater or less degree ever since: the Americans now make gloves for themselves and the French rival us in foreign markets. Still we bid fair to maintain a competition with them, the chief labour in this article (that of women) being almost as cheap in England as on the Continent. Worcester, Yeovil, Ludlow, and Woodstock are the chief seats of the glove manufacture.

Silk.

The circumstances of our silk manufacture are very different from those of our hardware. The whole of

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the raw material must be imported: our canals are of no importance in regard to an article so light in comparison with its value; and even the cheapness of our fuel is in this respect but a secondary advantage. How then has it happened that the silk manufacture gained a footing in England? It seems to have owed its introduction to the large profits expected from an article costly in itself and consequently used by the higher classes. It was begun in this Country before the year 1500, and attained a certain extent in the course of the XVIth Century, particularly in the reign of Elizabeth, when a number of Flemish workmen settled in England in consequence of the political disturbances in the Netherlands. A further stimulus was given to it a century after by the repeal, in France, of the Edict of Nantes, and the removal of a number of the manufacturers to England. Unfortunately our Government began at that time to listen to the doctrine of monopolists, considering it politic to subject foreign silks to a high duty, and eventually to prohibit them *in toto*. Italy was then the quarter for supplying us with silk, whether raw or organzine, or, as it is commonly called, thrown silk. But in the year 1719, a Mr. Lombe, afterwards Sir Thomas Lombe, having obtained models of silk mills from Italy, established one at Derby for the purpose of throwing silk. To perform this process in England was accounted at the time a great acquisition; but there is now little doubt that the silk manufacture would have succeeded better in this Country had we been content to leave things to their natural course, and to impose no restraint on the import of thrown silk, while the duty on the manufactured article ought not to have exceeded ten or fifteen per cent. With so moderate a duty there would have been very little inducement to run the risk of smuggling foreign silks: the competition would have been open, and Government would soon have been enabled to judge whether the manufacture could stand its ground in this Country without factitious aid. But the course pursued was very different; foreign silks were either burdened with a very high duty or prohibited; a strong temptation was thus afforded to smuggling; and the amount of foreign silks clandestinely imported was probably not below half a million sterling a year, which a century ago was a very large sum. Hence a succession of complaints on the part of the workmen in Spitalfields, one of the results of which was an Act of Parliament obliging the masters to pay them wages according to a fixed scale. This compulsory Act ended, as compulsion in Commercial affairs always does, by defeating its own object; the manufacturers, in self-defence, established silk-weaving in Provincial towns, (Manchester, Norwich, Leek, Macclesfield,) which were out of the reach of the Act; and the result of the competition was a reduction in the rate of wages in Spitalfields.

Progress of this manufacture.

However, notwithstanding complaints on the part both of the workmen and their employers, the silk manufacture was continued and increased in correspondence with our population, so that towards the year 1785 the value of the silk annually made in England was computed to be nearly £5,000,000. It then began to suffer from the rivalship of cotton, which every year became more formidable as mechanical improvements followed each other. In the course of years, cotton fabrics became almost as elegant and, beyond all comparison, cheaper than silk: no effort on the part of the East India Company to reduce the cost and increase the quantity of silk imported from Bengal, could balance the cheapness of cotton, and the ease with which, from the nature of its fibre, it admits of the application of machinery. The latter advantage it possesses in a remarkable degree over wool, flax, and silk; so that the mechanical improvements in the manufacture of those articles have, in general, been first tried and made to succeed in cotton.

Rivalship of cotton.

The consequence of the rivalship of a manufacture improving so rapidly as that of cotton, has been a frequent depression of the silk trade, and a recurrence of complaints among the weavers, chiefly in Spitalfields, but occasionally also in Coventry, Macclesfield, and the other Provincial seats of this manufacture. At last, in 1825, Government adopted a new system; the prohibition of foreign silks was declared at an end, and their import was allowed on paying a duty of 30 per cent. *ad valorem*. The duty on foreign thrown silk was lowered from 14*s*. 7*d*. per pound to 5*s*. The reduced rates were accounted by Government sufficient to protect both our throwsters and weavers; and in order to afford them raw silk at a cheap rate, the duty on it was brought down to 3*d*. per pound.

This Act has now been in operation seven years, a period of severe trial to the silk trade as to all ornamental manufactures, in consequence of the reduced circumstances of the majority of the consumers. Complaints have continued on the part of our manufacturers, and a higher duty on foreign silks has been called for; but, on the other side of the question, reference has been made to the rapid increase of the manufacture. This fact is established by the increased import of the raw material, which in the course of ten years has doubled: it is further shown by the increase of our exports, which though not yet large, (£400,000,) are fully double their former amount. It has now become a general opinion, that in all qualities of silk, except fancy goods, our workmen are equal to those of France, while in several they are superior.

The number of weavers and other persons, young and old, employed in the silk trade, is not accurately ascertained, but is computed to exceed 100,000 in the whole Kingdom. The value made annually, in an article so high priced, is large in proportion to the number of persons employed; not less probably than £10,000,000 sterling. Our chief export is to the United States of America.

Extent of the manufacture.

So far from acceding to an increase of the existing duty on foreign silks, the advocates of free trade contend that it would be for the advantage of our manufacturers if it were lowered to 15 per cent., as smuggling would then cease. Be this as it may, the remarkable difference in the success of the cotton and silk manufactures in this Country seems to have originated in the following causes.

1. The silk manufacture was long confined to London, where provisions, fuel, and house rent are and have long been considerably higher than in Lancashire.

2. The French and Italians had, in a manner, preceded us in regard to silks, while the production and supply of cotton for manufacture became large only at a time when our disposable capital had become great, when the supply of coal was extended by canals, and our town population was rapidly on the increase. Foreigners could buy the raw material as cheaply as our Countrymen, but they were greatly inferior to us both in capital and machinery.

3. To these the advocates of free trade add the advantage of leaving a manufacture to its natural

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course; the interference of Government, even for the purpose of protection, being found in most cases to be eventually injurious.

Lace and stockings.

Connected with the silk manufacture are the lesser branches of lace and stockings. Lace is made in large quantities in the midland Counties, *viz.* Buckingham, Bedford, and Nottingham. It is a manufacture of old date, and formerly gave employment to very many persons, chiefly females, to the number, it is said, of nearly 200,000 in all. The quantity of lace made in England is at present greater than ever, but machinery has in various respects superseded manual labour. Since the General Peace in 1815, the price of lace of all kinds has fallen greatly, so that the wages of the women employed, as well as of the workmen engaged on the power and hand looms, are much lower than formerly. Our chief rivals in this manufacture are in Flanders, which has long been noted for the variety and quality of its lace, and still preserves a superiority in embroidery.

The stocking manufacture is carried on likewise in the inland Counties of Nottingham, Derby, and Leicester; the quantity made annually is now greater than ever, but in this branch also machinery has greatly superseded manual labour. The value of the cotton and silk stockings woven annually in England is not below £2,500,000.

Earthenware

We come in the next place to manufactures of a more homely nature, but which are likely, in the course of time, to acquire great extension in this Country, in consequence of our local advantages. The cheapness of our fuel is a first-rate point in making both glass and earthenware; while the extent of our canals is of equal consequence in sending them to a market. Both advantages are enjoyed at Newcastle in regard to glass, and in Staffordshire (in the Pottery district) in respect to earthenware. In the latter district a population of above 60,000 persons is engaged in preparing for market as well the porcelain or finer qualities, as the cheap and bulky earthenware required for common use. The value of the whole made annually at the Potteries is computed at £1,500,000, and of that made at Worcester, Derby, and other parts, at between £700,000 and £800,000. The portion of the whole exported yearly is about £500,000. The United States of America are our principal foreign market, and next to them Brazil and the West Indies.

and glass.

In the XIVth and XVth Centuries the making of white glass was, in a manner, confined to Venice, and the chief towns of Italy; while, from the expense attending its conveyance to England, its price was such as to confine its use to the Court, the Nobility, and a few affluent merchants. It was in the latter part of the reign of Elizabeth, somewhat more than two centuries ago, that the improving circumstances of our farmers, manufacturers, and middle ranks generally, enabled them to adopt the use of what was at that time considered a luxury: hence a motive for manufacturing glass at home, particularly in the vicinity of our coal mines. The French have long carried, and still carry on this manufacture with spirit, but with means inferior to ours, both as to fuel and conveyance by water. The total yearly value of the glass made in Great Britain is about £2,000,000; that of the exports £500,000.

Sugar refinery.

Another manufacture in which our abundance of fuel is of the greatest importance, is the refining of sugar; this is carried on to a great extent in England, as well for home-consumption as for export. The latter, however, has been subjected to repeated checks from the duties imposed on the import of our refined sugars at Hamburg, St. Petersburg, and other ports, in which the respective Governments have endeavoured to confine the manufacture to their own citizens or subjects. The Germans, our chief rivals in this branch, have the advantage of cheap labour and of workmen accustomed to the business: we, on the other hand, obtain raw sugar at a somewhat lower rate, and have, in most situations, a cheaper supply of fuel. Our refineries are chiefly in London, Bristol, Liverpool, and Newcastle: in London, Bristol, and Liverpool, the refiners are supplied with raw sugar landed on the spot; at Newcastle, the want of this advantage is compensated, and perhaps more than compensated, by the cheapness of fuel. But whether in London or the outports, the workmen employed in this exhausting manufacture are chiefly Germans. The value of the refined sugar annually exported from England is about £2,000,000, and the chief markets are Italy and Germany.

Soap.

In the South of Europe, the climate being favourable to the growth of olives, olive-oil is so abundant as to be the raw material for the manufacture of soap; but in England and other Northern Countries recourse is had to inferior materials, *viz.* tallow, soda, and potash. The quantity of soap made annually in England is between 50,000 and 60,000 tons, the value of which is about £1,500,000, or, after adding a very heavy excise duty, (3*d.* a pound,) £3,000,000. The latter is, of course, the sum paid by the Public for an article on which the duty ought to be moderate, as well from its being indispensable to cleanliness, as from the smuggling to which the high impost has given rise.

Hats.

The total value of the hats made annually in Great Britain is between £2,000,000 and £3,000,000 sterling: the materials are the fur of the beaver for the finer hats, and wool for the coarser, or, as they are commonly called, felt hats. Having no superiority over neighbouring Countries, either in the purchase of these articles, or in the process of the manufacture, we do not export hats to the Continent of Europe: our foreign markets are confined to our colonies and Brazil, and the amount sent abroad not being above £200,000 annually, nine-tenths of the hats made in England are consumed at home.

The Brewery and distillery.

We pass now to objects of a very different nature—to the produce of our breweries and distilleries. There are eleven Porter Breweries in London, which collectively brew about two millions of barrels of porter annually. The higher wages of labour in London and the higher price of fuel, have led to competition in Provincial towns in various branches, but not in porter brewing, because those drawbacks are counterbalanced by the great advantage of a market on the spot, nine-tenths of the beer made being consumed in the Metropolis and its vicinity.

In regard to a different liquor, spirits distilled from corn, the advantage of a market on the spot is of less importance, the freight from a distant port being a less serious charge on an article which is of considerable value for its bulk. The London distillers must therefore reckon on a continual competition with Scotland and the North of Ireland, notwithstanding the advantage to London of the late reduction in the coal-duty.

Malt has been subjected to an excise duty in England above a century and a half, and if the returns of the

Commerce. Public Offices be assumed as a fair criterion of the quantity of beer annually consumed, the result is that its increase has borne a very inadequate proportion to the increase of our population. Thus in the forty years between 1787 and 1827, our numbers increased between 70 and 80 per cent., while the quantity of beer sold hardly increased 30 per cent. The means of purchase on the part of the lower orders having augmented in the course of that period, to what are we to ascribe their limited consumption of beer? To two causes: the extended use of tea and coffee, and the unreasonable amount of the beer duty, which exceeded the prime cost of the article until so lately as 1830, when it was reduced. The quantity of barley made into malt in England has not during many years exceeded an average of 3,300,000 quarters; but now that the duties on both beer and spirits are so materially reduced, the quantity of barley made into malt is in a course of progressive increase. The motive for lowering the duty on beer was twofold: the relief of the lower orders, and the benefit of the agriculturists. In the case of spirits the ground of reduction was different; it was to check illicit distilling, which prevailed to a most pernicious extent in Ireland and Scotland. That effect it produced, and the consumption of the different parts of the United Kingdom is now understood to be almost wholly of duty-paid spirits. The yearly average may be stated thus:

Ireland, 9,000,000 gallons of home-made spirit.
Scotland 6,000,000 ditto.
England, 8,000,000 ditto.

But of the quantity prepared in Scotland a considerable part is for the English market, in which there is also a consumption of rum and brandy far beyond that of the other proportions of the Empire.

Mineral Products.

Lead. Lead mines were wrought in Derbyshire before the XIIIth Century: at present they are worked not only in that County, but in Cumberland, Yorkshire, and Wales. The quantity formerly raised from our mines was above 20,000 tons annually, of which the half was exported. Of late years, however, the quantity of our exports has been much lessened by the [illegible]ship of lead mines in the South of Spain, the ores of which are much more productive than those of this Country, and are wrought, of course, at less expense. The consequence has been a great decline in the price of lead; *viz.* from £23 to £14 per ton since the year 1820, so that many of the workmen in our mines have been obliged to emigrate.

Tin. In tin there is less dread of foreign competition, few Countries in Europe being possessed of tin mines: the chief rivalship in that respect is from a very distant quarter—the tin mines in the Island of Banca wrought by Chinese settlers. The produce of these mines is brought chiefly to Singapore, and is shipped in vessels which call at that port in their voyage homeward from China. The quantity of tin yearly prepared in England is between 4000 and 5000 tons, almost all in Cornwall; the average value is nearly £4 per hundred weight.

Copper. The copper mines of England are chiefly in Cornwall, and the quantity raised from them has been greatly increased during the last fifty years. Instead of 2000 or 3000 tons, the former produce, the quantity raised at present is 12,000 tons, of which more than one half is exported. The increase in the produce of our copper mines has been owing less to discoveries of ore than to the successful application of steam-engines to clearing the mines of water. Coal in Cornwall being brought from a distance, and consequently rather high-priced, it is necessary to study economy in its consumption; in other words to raise the water by pumping with as small a quantity of fuel as possible. Successive improvements have carried this economy of fuel to a great length; the shape of the boilers has been altered, and the air excluded with a degree of care unknown in Northumberland and Staffordshire, where coals are abundant and cheap. The consequence of this, and of the reduced cost of labour and materials, is, that our copper mines are at present in a prosperous state, although their produce is sold considerably below its former price.

The importance of our coal mines, great at all times, has increased surprisingly since the extension of our canals and the application of steam to mechanical purposes. An eminent French writer, aware how much we owe to this precious mineral, calls coal *cette vive force en lingots;* and a Writer of our own Country describes it as "hoarded power applicable to almost any purpose which human labour directed by ingenuity can accomplish." The quantity of coal consumed in London has been increased from time to time with the population of the Metropolis. It was in 1700 about 350,000 chaldrons; in 1750 about 500,000; in 1800 about 900,000; and at present (1832) about 1,600,000. The consumption for the whole Kingdom appears to be nearly 16,000,000 tons, including the large quantities used in manufactures, particularly in the making of iron, the smelting of copper and other metals. Coal.

The coal trade has long been one of the chief nurseries of our seamen. The number of men and boys employed in the coal trade between the Northern sea-ports and the Metropolis is about 15,000.

The export of coal was formerly subjected to a heavy duty, *viz.* seventeen shillings and sixpence per chaldron: this is now reduced to three shillings and fourpence, and safely may we increase our sales to foreigners, for the coal fields of this Country are so extensive as to afford a supply which at the present rate of consumption, would probably last more than a thousand years. Nor is it likely that the amount consumed in England will increase in proportion to our population, since there are various methods of economizing coal, of which we need only mention one of very easy application, that of heating buildings by steam.

The coal conveyed coastways, particularly to London, was long subject to a heavy duty, thus increasing greatly the cost of an article already enhanced by the charge of freight. This ill-judged and pernicious tax proved a drawback on the industry of all the Southern Counties: happily it is now repealed, as is an equally objectionable tax on coal brought by canals from Staffordshire and other inland Counties.

Salt, which in all Countries is of great importance for consumption, is in England valuable likewise as an article of export. It is obtained chiefly in Cheshire in the neighbourhood of Northwich, where there are vast quantities of rock salt in the mines, and of brine or salt-water in the springs. The rock salt when dug out is not sufficiently pure for use, but when mixed with the brine from the springs and refined in large iron pans, it is called white salt, and forms a great object of export from Liverpool to the United States of America. During the late wars Salt.

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with France salt was subjected to a very high duty; this was repealed in the year 1823, and although all the advantages anticipated from the repeal have not yet been realized, there seems little doubt that the Public will gain more by the unrestricted use of so valuable a commodity than by the produce of the tax, large as it was.

In the South of France, and in other warm Countries, salt is obtained by evaporating sea-water by the heat of the sun: the crystals of salt made in that way are accounted purer than the salt of the mines, in consequence of the comparative slowness of the process. A small quantity (8000 or 9000 tons) of sea-salt thus prepared is imported annually from Portugal into England. The quantity of English salt consumed in this Country is computed at 150,000 tons annually; but the quantity sent abroad is considerably greater. The chief foreign markets are the United States of America, British North America, Russia, Prussia, and the Netherlands. In each of these Countries it is less expensive to pay the freight of salt on vessels coming from Liverpool, than to pay the land carriage of salt from their own mines, or to evaporate it from sea-water at their respective ports; particularly in the Baltic, where the proportion of salt in sea-water is much less than in the Ocean.

The Shipping of England.

Its progressive increase.

The mercantile shipping of England was quite insignificant until the time of Henry VII.; it increased progressively during the reigns of that Prince and his successors of the Tudor and Stuart race, yet so slowly that at the Restoration, in 1660, it hardly amounted to 100,000 tons. In the period between 1660 and 1689 the increase was rapid, because our Navigation Laws had come into full operation, and during several years (from 1674 to 1679) our flag had all the benefit of neutrality, the Dutch, who were then the great monopolists of shipping business, being involved in war with France. In our subsequent contest with the latter Power (from 1689 to 1697) our mercantile tonnage was necessarily lessened, but during the ensuing interval of Peace it recovered, and was found in 1702 to amount to 270,000 tons, manned by 27,000 seamen. In the present Age of extended navigation it is curious to observe the slender returns made on that occasion from our principal sea-ports:

	Vessels.	Seamen.
In 1702, London	560	10,000
Bristol	165	2,400
Hull	115	1,200
Liverpool	102	1,100
Exeter	120	1,000
Yarmouth	143	700

The following Table exhibits the remarkable increase of our shipping during last Century.

British Shipping after 1702. Tonnage of the Vessels cleared outwards in various years.

Years.	Tonnage.
1709	244,000
1715	421,000
1728	433,000
1738	476,000
1750	610,000
1765	726,000
1774	900,000
1785	1,075,000
1789	1,515,000
1802	1,627,000

As we draw nearer to the present time the returns of our mercantile navy are more complete.

British Shipping engaged in Foreign Trade (distinct from the Coasting Trade,) which entered inwards in the following Years.

Years.	Tonnage.	Seamen.
1820	1,668,000	100,000
1824	1,797,000	109,000
1828	2,094,000	119,000
1829	2,184,000	122,000
1830	2,180,000	122,000

Tonnage of the Merchant Vessels belonging to our principal Seaports in 1829.

	Tonnage.
London	573,000
Newcastle	202,000
Liverpool	162,000
Sunderland	108,000
Whitehaven	73,000
Hull	72,000
Bristol	50,000
Aberdeen	46,000
Yarmouth	44,000
Whitby	42,000
Glasgow	41,000
Greenock	36,000
Dundee	32,000
Scarborough	28,000
Leith	26,000
Plymouth	25,000
Belfast	25,000
Dublin	24,000
Dartmouth	24,000
Grangemouth (Scotland)	24,000
Beaumaris	22,000
Cork	17,000
All the lesser Ports	504,000
Total of the United Kingdom	2,200,000
British plantations	317,000
Seamen belonging to the mercantile shipping of Great Britain and Ireland in 1829	134,500
Seamen belonging to the British Plantations	20,000

Decline in the value of shipping.

No part of the mercantile community has suffered more severely since the Peace than the shipping interest, and in no branch of our industry is the competition of foreigners more to be dreaded than in shipbuilding. The cost of provisions being so much less abroad, the wages of shipwrights are comparatively low, while in some quarters, particularly in the ports of Norway and the Baltic, timber is much cheaper. Shipbuilding, in England, has consequently diminished; from 100,000 to 150,000 tons is the measurement now annually constructed; and that chiefly owing to our Navigation Laws, which, notwithstanding the relaxation of late years, require that British built vessels should still be exclusively employed in several important branches. This applies as well to the home trade as to the trade with our colonies, India, and China.

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Ports for ship-build-

Our merchant vessels were formerly built in a great measure at Blackwall, Woolwich, and other yards on the Thames; hence the name of "river built;" but the lower wages of the Northern ports have long since attracted the chief part of this business to

Hull,	Whitby,
Newcastle,	Scarborough,
Sunderland,	Whitehaven.

The vicinity of the New Forest to Southampton and of the Forest of Dean to Chepstow, led during the late War to establishments for ship-building at those ports, but they have as yet been attended with little advantage to the speculators. Nor does it seem likely that, in any part of the Kingdom, the distress of the ship-builders will be effectually relieved until the duty on Baltic timber shall be repealed or materially reduced. When a measure of that kind shall be adopted, the intelligence of our workmen, their better tools, and the greater capital of their employers, may enable us to maintain a competition with the ship-builders of the Baltic and the United States of America.

The mercantile shipping employed in our trade with Canada and our other North American

Colonies amounts to	400,000 tons.
With our West India Colonies	220,000
With the East Indies	100,000
With China	20,000

The number of vessels, generally small, employed in our coasting trade and in our intercourse with Ireland is about 3000; of which the half in tonnage, if not in number, belong to the coal trade.

The fish eries.

It has often been matter of surprise, that with such abundance of fish on our coasts, and such liberal encouragement from Government, our fisheries should not have attained a greater extension. The value of all the fish caught on our coasts and in our rivers does not exceed £2,500,000, not one-tenth part of the price of the butcher's meat annually consumed in England. This is to be ascribed, partly to the frequency and long duration of our Wars, partly to the inefficacy of systems of bounty in almost any form. Something also is to be attributed to the sale of fish in London having until lately been confined to one market. The removal of that abuse, joined to the additional capital and number of hands now employed in the fishery, will greatly increase the quantity of fish brought to the Metropolis and the inland towns. Accelerated conveyance by steam-boats and steam-carriages will operate to the same result. At times when, as in the year 1812, bread and butcher's meat were high-priced, the experiments made in forwarding fish to inland districts were highly encouraging; large quantities, slightly corned, having been sent from the coast to the interior at a charge almost too inconsiderable to be named.

The Newfoundland fishery has long been conducted on an extensive scale, and employs about 6000 seamen. But the herring fishery on our coasts has been the chief object of bounty on the part of Government, for the double purpose of enabling our Countrymen to compete with the Dutch, and to render the fishery a nursery for seamen. Many years ago a bounty was given on the busses or vessels employed in this fishery: subsequently, in 1808, the bounty was extended, and was paid partly on the tonnage employed, partly on the quantity of fish caught and cured. After the general Peace of 1815, the form of the bounty was further altered, and was awarded solely in proportion to the quantity caught. Of late years, however, the rule of withdrawing all artificial encouragement has been applied to this branch of our industry; the bounty has totally ceased since 1830, and it is considered that in this, as in the case of silk, the capital and labour employed will now be better rewarded than when the bounty was in operation. Men engaged in other employments, who used to go to sea during a few months in Summer for the sake of the bounty, are now withdrawing and leaving the business to fishermen, who make it their regular and almost constant occupation.

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Summary of our Imports and Exports.

Our imports distinguished by the respective Countries.

The chief articles of import from other Countries into England are the following.

From Ireland; linens, oats, wheat, cattle, pigs, salted provisions and butter, the whole forming an amount of £6,000,000 or £7,000,000 annually.

From the Baltic, *viz.* Russia, Poland, Prussia, Sweden; timber, pitch, tallow, iron, wheat, hemp, flax, pot-ash.

From Holland; oats, wheat, seeds, cheese, butter, also gin.

From France; wine, brandy, silk, lace.

From Germany; corn, wool, flax, linen, also timber and Rhenish wine.

From Spain and Portugal; wine, brandy, oil, fruit.

From Italy and the Levant; silk, oil, fruit, and drugs.

From Egypt; cotton.

From the United States of America; cotton, tobacco, rice, and flour.

From South America; cotton, hides, indigo, cochineal.

From the West Indies; sugar, rum, coffee, cotton, pimento.

From the East Indies; indigo, silk, cotton, sugar, spiceries, and occasionally rice.

From China; tea, silk, nankeens, tin.

From Canada, Nova Scotia, New Brunswick, Newfoundland; furs, skins, timber, fish, and seal-skins.

Exports.

Such are our principal articles of import. Our exports consist of cottons and hardware to almost all the Countries mentioned above; of woollens, linens, earthenware, to most of these Countries: and to a smaller number, of refined sugar, coffee, indigo, glass, machinery, coals, fish, to which are to be added articles of a very different nature, *viz.* silk, stationery, hats; all, or almost all, being manufactures, while our imports are generally of raw produce.

Next, as to the amount in money of our imports and exports.

Value of our annual Imports from and Exports to Foreign Countries; being an average of several years, but having reference more particularly to the year 1829.

	Imports from	Exports to
Russia	£4,000,000	£3,000,000
Sweden and Norway	250,000	300,000
Denmark	480,000	250,000
Prussia	1,300,000	800,000
Germany	2,000,000	10,000,000
Netherlands	2,000,000	5,000,000
France	2,000,000	1,000,000
Portugal and Madeira	400,000	2,000,000
Spain	1,000,000	3,000,000
Italy	800,000	4,000,000
Turkey and Greece	500,000	1,500,000

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	Imports from		Exports to
Egypt	£250,000	..	£130,000
Cape of Good Hope	250,000	..	380,000
West Coast of Africa	250,000	..	500,000
Mauritius	500,000	..	300,000
New South Wales	120,000	..	300,000
British North America	900,000	..	2,000,000
West Indies	8,000,000	..	5,000,000
United States of America	6,000,000	..	6,000,000
Mexico and Columbia, (exclusive of silver)	250,000	..	1,000,000
Buenos Ayres	500,000	..	1,300,000
Brazil	1,500,000	..	4,000,000

Mode of liquidating balances.

With some Countries, such as the United States of America, the amount in money of our imports and exports is nearly equal: with others, such as Germany, Spain, and France, the difference is great; to a degree, indeed, which makes it at first difficult to understand in what manner the balances are liquidated. The means of doing so are partly by the transmission of specie, but more by bills of exchange drawn by the merchants of one Country on those of another, for example, from Brazil on Portugal. These, when remitted to London, form a fund for paying to our merchants a part of the balances annually due to them by Brazil. The *bourses*, or mercantile exchanges of London, Amsterdam, Paris, Hamburgh, and, in a lesser degree, those of Lisbon, Cadiz, Frankfort, are the central points for such negotiations for the sale and purchase of the bills, by means of which the debts of one nation to another are liquidated with comparatively little transfer of coin or bullion. This arrangement may be compared to the manner in which the London bankers discharge their daily balances with each other by an exchange of cheques, without requiring any large sum in Bank notes. So far do the bankers carry this economy of money, that balances amounting to £4,000,000 may be, and generally are liquidated without using more than £200,000 in notes.

Low valuation of imports.

It is fit to add that the mode of valuing the imports in the preceding Table is different from that of valuing the exports. The latter are estimated at the market price, agreeably to the sums declared by the exporting merchants; the former by an official scale established so long since as 1696, when the prices of most of the articles we import were lower than at present. Were our imports rated at the current or market price, the sums would be considerably larger, and there would consequently be a greater approach to equality in the value of our imports and exports. We subjoin a Table of the

Value of our Exports classed, not by the Countries to which they are sent, but by the respective articles.

Cotton cloth	£13,000,000
Cotton yarn	2,000,000
Woollens	5,000,000
Linen (chiefly Irish)	2,000,000
Iron and steel	1,300,000
Hardware and cutlery	1,400,000
Brass and copper articles	700,000
Lead and shot	180,000
Tin, wrought and unwrought	350,000
Machinery and mill work	300,000
Silks	400,000
Haberdashery and millinery	500,000
Earthenware	500,000
Glass	500,000
Leather, *viz.* shoes, saddlery, harness	£350,000
Sugar, chiefly refined	2,000,000
Soap and candles	270,000
Hats	200,000
Salt	300,000
Beef and pork salted	150,000
Fish	300,000
Coals	400,000
Beer and ale	300,000
All lesser articles, whether of produce or manufacture	5,000,000

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The above is the value as declared by the shipping merchants, and applies to the years 1830 and 1831.

Trade of England compared with that of the United States of America.

The preceding statements may receive some illustration by a comparison of the trade of this Country with that of our Transatlantic brethren. While the imports into England consist chiefly of raw produce, or the materials of manufacture, such as cotton, wool, timber, and our exports are almost wholly of manufactures,—in the United States, the reverse holds in both respects. There, the imports consist of manufactured goods, the exports of raw produce. The causes in either case are obvious; England has an abundant population with a limited territory; while in America, the population is still thinly spread, and the territorial surface is almost boundless.

The Tariff of 1828.

It has been the practice of almost every Government in Europe to study an indiscriminate extension of manufactures without much attention to the limitations rendered proper by the nature of their respective territories; hence the endless prohibitions and high duties on foreign articles under the mercantile system. To that system a number of our merchants and some of our public men are still attached, and the Americans, much as they have professed to admire freedom in trade, have given an unfortunate proof of the contrary by the Tariff enacted in 1828, which burdens all foreign manufactures with heavy duties. By what means was an act so contrary to the general rules of the American Government passed into a law? By the influence of the manufacturers; for the Tariff is an attempt to confine to that interest the supply of manufactures of almost every kind consumed in the States; in particular cottons and woollens. This Tariff has already been the source of much division between the different States of the Union; it has of late been somewhat modified, but cannot fail, if persisted in, to lead to very serious discontents. The extent of evil arising from it has not yet been fully developed, but it will, we may be assured, be as great as that which this Country has so long suffered from the imprudent interference of Government in former Ages with the natural course of trade.

Manufactures unsuited to the United States.

The chief obstacles to manufacturing industry in America are the high price of labour, the want of good roads, and the remoteness of the towns from each other. Ages must pass before these drawbacks can be removed, and at present it would evidently be more advisable to direct the surplus capital and labour of the Country to the culture of the soil. The chief products of the United States, wheat, cotton, tobacco, rice, have all, it is true, fallen greatly in price since the Peace; yet that ought not to discourage the cultivation of articles for which the market is so extensive, embracing, as it does, the West Indies, South America, England, and several Countries in Europe.

The situation of England in respect to manufactures

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is quite different from that of the United States; we possess remarkable advantages in

Advantages of England as a manufacturing Country.

1. The cheapness of fuel, and the consequent facility of applying steam to machinery.

2. In case of communication, whether by sea, by canals, or by roads.

3. In the cheapness of iron, and a decided superiority in all machinery and tools made of iron.

These are physical advantages; but to them we may add others of a different kind almost equally important, *viz.*

The lower rate of interest consequent on the magnitude of our disposable capital; and

The division and subdivision of employment, particularly since the population of our towns has received so great an increase in the present Age.

Our disadvantages.

On the other hand, we are subject to several drawbacks; they are as follows:

1. The price of provisions, which, though greatly reduced, are still from 10 to 15 per cent. above the rate of our foreign rivals.

2. The pressure of taxation, or rather of particular taxes, such as that on timber, which cramps our intercourse with the Baltic, and that on sugar, the amount of which is so great as almost to ruin our West India planters.

3. In high charges resulting from the War and a depreciated currency. In the case of articles sold in open market, such as corn and manufactures, the war charges have fallen long since; but they still exist in an oppressive form in other cases, such as the rent of land let on lease, in the rent of houses, in professional fees, and in various other demands, in which our laws and usages are such as hardly to allow of a direct or speedy reduction.

Computed profit from our manufactures and trade.

After these ample details of our commercial industry, it would be desirable to convey an estimate of the annual profit attendant on undertakings so vast. No attempt was made to calculate such profit until the imposition of the Property-tax in the beginning of this century, when, among the other returns to the treasury, there appeared one of the collective income of our merchants and manufacturers. Mr. Pitt forming, as persons not engaged in trade are generally inclined to do, a high estimate of its profits, had computed the probable amount of mercantile income in Great Britain at forty millions annually; but the returns made under the Act proved considerably less, having in no year exceeded thirty millions. There were, no doubt, many cases in which mercantile men declared less than their real income; but, on the other hand, there were not wanting examples of their continuing to return the usual amount of income in years in which they had sustained heavy losses; their apprehension being that a diminished return might affect their credit.

What, it may be asked, is the probable amount of the income of our merchants and manufacturers at present, compared to its amount during the War? The number of persons employed in Commerce is, doubtless, far greater at present, but there is, and has long been, a general complaint of insufficient profit, even in the branches which have received the greatest extension, such as cotton and hardware. The causes of this are sufficiently clear; during the War, the keenness of competition was greatly lessened by the demands of Government; the public service attracted annually many thousands of our population and many millions of our capital; hence a continued rise in prices as well as in the wages and incomes of all ranks. But since the Peace, capital, intelligence, labour, have all returned to their natural channels and been directed to the increase of products. This, added to the changes in the currency, has caused a great and general fall in prices, wages, and incomes; and although the number of persons employed in this Country in trade and manufactures is greater by fully 30 or 40 per cent. than it was twenty years ago, it is very questionable whether the income of this augmented number, if returned in money, would be at all equal to that of the same classes during the War. We say, "if returned in money," because there can be little doubt that in the power of purchasing goods, the present income of our merchants and manufacturers is considerably greater than during the War in consequence of the comparative cheapness of commodities.

Fluctuations in the currency.

This leads to the consideration of the greatest of all the changes that have taken place in the state of Commerce during the present Age—the change in the value of gold and silver. During twenty years (from 1793 to 1813) prices were progressively on the rise, and during a period nearly as long, they have been, with very few intervals, on the decline. Many persons ascribe this decline to the reduced supply of gold and silver, the mines of America, formerly so productive, having, during the last twenty years, yielded less than half their usual amount. Whatever be the cause, the extent of loss from declining prices is enormous; nor can any one say with confidence how the evil is to end. The deficiency in the produce of the American mines continues year after year, and the present management of them, whether by the native owners or the English Companies, is much less successful than that which was followed in the time of the Spanish Government. We have seen in a preceding part of this Essay (p. 90, 91.) how greatly the influx of gold and silver from America extended the trade of Europe in the XVIth and XVIIth Centuries; and it is a matter of the greatest interest to ascertain how far it may be possible to lessen the pressure at present so severely felt from their diminished supply. To arrive at a decided opinion on this subject, it is requisite to go back to an early period in the production of the precious metals, a subject closely connected with the History of Commerce, and on which considerable light has been thrown by a late publication of Mr. Jacob, of the Board of Trade, already known to the Public by his Reports on the Agriculture of Germany and Poland. Mr. Jacob's book discovers extensive research, and exhibits in connection a great deal of information which had previously existed in a very scattered state.

The Precious Metals; Historical Sketch of their Production, and of their Influence on Commerce.

Gold and silver appear to have been in estimation at an early period in every Country of which we possess records. This was a natural consequence of the beauty and durability of these metals: valued at first as ornaments, their use as a circulating medium began subsequently, and for many years after it did begin, they were paid and received by weight, and not in the form of coin, for coin requires an established Government, as well as an improved state of Society. Abraham, the earliest Patriarch of whom we have a circumstantial history, and who lived about nineteen centuries before the Christian Era, is described in Scripture as rich in those metals, and as paying for his purchases in silver, not in coin but by weight, "according to the currency of the merchant." Gold was too scarce and too valuable to form the circu-

Circulated at first by weight.

lating medium of that early Age: it was used almost wholly for ornament, like sapphires, pearls, rubies, and other jewels. In this manner it was applied by King Solomon in building the Temple at Jerusalem and the Royal Palace. "He overlaid," we are told in Scripture, "the oracle with gold; also the whole altar that was by the oracle, he overlaid with gold." We have already noticed (page 79.) the extension of the trade of Judæa at that epoch. The quantity of gold brought into the Royal coffers in the reign of Solomon appears to have been between £200,000 and £300,000 sterling a year; that of the silver brought in is not distinctly stated. At that time the only wealthy Countries were Assyria, Egypt, and Judæa, for Greece was then only in a primitive stage of civilization.

The early Annals of the Jews are of great interest to the student of Ancient History, as furnishing information not only of themselves, but of the Egyptians and Phœnicians, long before it could have been obtained from any other quarter. The earliest date of written records in Greece was later by five centuries than the time of Moses, and the promulgation of his laws in a written form. It appears from this and other facts in History, that the use of letters was known in Egypt much earlier than in Greece, for it was chiefly to the fortunate circumstance of Moses being educated at the Court of Pharaoh that he owed his superior attainments. "He was skilled," says the Scripture, "in all the learning of the Egyptians." The mines in Nubia and other parts, wrought for account of the Egyptian Government, had been so far productive as to replenish the public treasury, and afford to the industrious and prudent the means of laying up property in the portable form of gold and silver. By this the Israelites had profited; for it is apparent from Scripture, that on leaving Egypt, they carried with them a considerable stock of the precious metals. The additions made to this stock in their subsequent wars were generally lodged in the public treasury, and protected by the solemn sanction of Religion: all was kept in the Tabernacle under the title of "Treasure of Jehovah." It follows that the metallic wealth existing in so considerable an amount under Solomon, was the accumulation of successive Ages, and its extent is thus in no way inconsistent with his limited territory, or the still more limited property of his subjects. That politic Monarch married a daughter of the King of Egypt, and maintained a close alliance with Tyre, which was then at a high point of prosperity. There were happily no national jealousies to interfere with the cordiality of the two Countries: the Jews, amidst all their offensive wars, had had none with the Phœnicians, whose territory was fortunately at some distance from Judæa.

Egypt early civilized.

The public treasure in Jerusalem.

After the reign of Solomon, there took place, as is well known, great disorders in the Jewish Government, but amidst all these, the public treasure, or a considerable part of it, appears to have been preserved, and to have been removed to Babylon after the conquest of Judæa by Nebuchadnezzar. In Babylon this and much other treasure, conveyed thither from conquered Provinces, fell into the hands of the Persians on the conquest of the Empire by Cyrus. His successor Cambyses added to it an ample store from the treasury of Egypt. Persia was now the principal Empire in the World, and its yearly revenue is understood to have amounted to three or four millions sterling. By this is meant the clear sum forwarded by the Satraps, or Provincial Governors to the Royal exchequer, after defraying all local charges. But of this large amount very little was put into the form of coin. "The gold and silver," says Herodotus, "were melted and poured into earthen vessels, and these, when filled, were removed, leaving the metal in a solid mass. When wanted for payments, a piece was broken off of the amount required for the occasion, and issued in the shape of coin." The gold coins of that Age are the earliest of any specimens known to exist: they were called, after the reigning Monarch, Darics, and were worth each about twenty-five shillings of our present money.

The Treasury of Persia.

The treasury of Athens could not, of course, enter at all into comparison with that of the Monarchs of Persia. It received from the petty Islands of the Archipelago, and other tributaries, a yearly revenue of £120,000 sterling, and the sum accumulated at Athens before the Peloponnesian war, was equal to about £1,200,000 sterling. That sum, so much greater than the contents of any other treasury in Greece, was one main cause of Athens being enabled, notwithstanding her heavy losses, to make head against Sparta and her confederates during nearly thirty years.

Of Athens.

About a century after the brilliant era of Athens, the course of events led the Macedonian armies into the heart of Persia, and delivered the Royal treasures at Persepolis, Ecbatana, and other great cities, into the possession of Alexander. The amount of the whole is said to have been nearly £10,000,000 sterling, a sum far greater than had as yet been collected in any other Country, but not improbable when we consider that it continued to be the practice of the Persian Government not to coin and circulate their gold and silver, but to keep them stored.

Passing in the next place to Italy and the Romans, we find that the extension of their dominion had the natural effect of bringing large amounts in gold and silver to the Capital from the Countries successively conquered. These came first into the hands of the military commanders and of the Civil governors of Provinces. The use of coined gold and silver had not even then become general, so that a considerable time elapsed ere these treasures were circulated among the Public. they remained a long time in the coffers of the State.

Of Rome.

We are next to advert to the means of obtaining regular supplies of silver and other metals; to the Art of mining. That Art could not, it is evident, have been carried on in ancient times in a manner at all similar to the systematic and refined form which it now bears in Germany and England. A rude Tribe could begin only by working the ore found near the surface: when that was consumed, the working was necessarily carried on under ground; a task of great difficulty, deficient as they were in those Ages in tools and machinery. Egypt appears to have taken a lead in mining as in other useful Arts. The mines wrought for account of its Government were situated at a great distance, being in Nubia about latitude 22° North, distant nearly a fortnight's journey from Assuan, the ancient Syene. The rude mode of mining practised there appears to have borne a considerable resemblance to that which is still followed in Spanish America: the ores were brought to the surface, not as in this Country in baskets drawn or hoisted up a shaft, but on the backs of workmen, a practice still common in Mexico and Peru. Again the ore, when ground to a powder, was thrown into a gentle current of water, in which the metallic or heavy particles sank to the bottom, and the lighter or earthy were carried away by the stream. A supply of mining labourers was kept up somewhat on the plan adopted by the Russians in

Mining for silver and other metals.

In Nubia.

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Siberia; by sending thither captives taken in war, convicts, and all political delinquents, with their families. The produce of these and other mines wrought for the Government of Egypt greatly exceeded that of any other mines in ancient times.

Gold obtained from the sand of rivers.

Such was in early Ages the mode of obtaining silver as well as copper and iron: gold, on the other hand, was procured by a more uncertain, but less laborious process; by washing the sand brought down by streams from mountain districts. This practice prevailed in various parts of the ancient World; in the Eastern Provinces of Persia; in that part of India (the North-West) which was subject to the Persians; and even in the remote region of Abyssinia, great part of which being mountainous, has streams which supply the materials of such a traffic. The Abyssinians appear to have conveyed their gold-dust by the Red Sea to Egypt and Phœnicia, thus furnishing to Thebes in Upper Egypt an additional source of wealth.

Mines in Greece.

The Greeks acquired the Art of mining from the Phœnicians, and carried it on first in the Islands, such as Crete, Thasus, Eubœa; afterwards on the mainland, particularly in Attica. The work was performed by slaves, who belonged to the proprietors of the mines, and were hired by the adventurers or lessees of the mines at a fixed rate. The latter supplied them with provisions and clothing, and added, at the end of the month, a small payment in money, equal, in power of purchase, to about thirty shillings of our currency. In the mountainous parts of Thrace there were silver mines which had been wrought for Ages, but which falling into the hands of Philip of Macedon, were rendered far more productive under his politic management, and yielded him a portion of the treasures which he employed with such fatal effect against the independence of Greece.

In Thrace.

In Italy.

Turning from Greece to Italy, we find the first accounts of mining relate to Etruria, into which the useful Arts had been early introduced from Greece, by a colony from Corinth. The Etrurians obtained from their mines, first copper, afterwards iron. The copper required by the Romans for coin in the days of their republican simplicity was during several centuries drawn from Etruria. Gold was obtained in small quantities in two parts of the North of Italy: in the North-West, in the Province of Aosta, by washing the sands of the Po; and in the North-East of Italy, in the country round Aquileia, as well as in certain parts of Illyria.

In Spain.

Spain being one of the most mountainous Countries in Europe, and visited at an early epoch by the Phœnicians and Carthaginians, it was to be expected that its metallic treasures would be turned to account. Gades, or Cadiz, was one of the earliest settlements of the Phœnicians; Seville, Malaga, Carthagena, followed some time after; and in a few generations a number of smaller towns were formed by settlers from the East, for the natives of Spain were quite in a state of barbarism. The population being, moreover, very thinly spread, it became necessary for the working of the mines to bring over labourers from Africa. The mines first wrought for Phœnician account were probably situated along the base of the Sierra Moréna, near the Guadalquiver, by which their produce would be conveyed first to Seville, afterwards to the sea. In that quarter (at Guadal canal, in the Province of Cordova) was the silver mine of Bebulo, from which Hannibal is said to have stored his military chest before crossing the Alps, and striking such disastrous blows at the power of Rome.

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Mining under the Romans.

The Romans possessed no silver mines until the progress of their arms, in the first and second wars with Carthage, led to their occupying the mines of their adversaries in Sardinia, Sicily, and the South of Spain. They soon after obtained possession of the mines of Macedon, and at a subsequent date of those of Persia and Nubia. In ancient times nine-tenths of the manual labour done was performed by slaves; or, to speak more correctly, the lower orders employed in country work, in mining, or in almost any kind of labour, were paid more by maintenance than by money. The practice of paying the labourer in money, and leaving it to him to provide for himself and family, was then but partially followed; still less was it the rule to apportion the remuneration of mining workmen according to the produce of the ores they raised. The latter is the only effectual means of checking the expense of mining, and as a Public Body is ill fitted to enforce the economy requisite in fresh undertakings, the Roman Government allowed the mines of the State to be gradually abandoned; so that after the Vth Century there seems to have been, in a manner, an end to mining for the public account. For account of individuals, mining was still carried on in certain parts, but we are now arrived at the Dark Ages, when there is a failure of records of various kinds, and of none more than of those relating to the precious metals. One thing admits of little doubt, *viz.* that from the reduced supply of gold and silver, there was a gradual reduction in the money prices of commodities in the latter Ages of the Empire; that is, an ounce of silver or gold then went farther in the purchase of commodities than in the flourishing times of Rome—in the days of Augustus and of Trajan.

Gold and silver scarce in the Middle Ages.

The laws passed from time to time by the Anglo-Saxon Princes prescribe the prices of certain commodities. Thus, those enacted about the year 1000 fixed the value of a horse at a price that would make 35*s.* of present money, that of a mare or colt at 23*s.*, of an ox or cow at only 7*s.* Cattle were then of very diminutive size, much inferior to those of later times; but the price prescribed for an ox or cow is so low as to be accounted for only by the uncultivated state of the Country; by tillage being limited to particular spots, while four-fifths of the land were forest or waste. Hence animal food was so cheap as to be an object in the market only after a bad season, when corn was scarce and dear: at other times the value of the animal in England was little more than the value of his hide, as is the case at present in the wilds of Russia and of Buenos Ayres.

Price of cattle in England in the Middle Ages.

Of wheat.

The price of wheat also in England during the Middle Ages is deserving of a few remarks. It is stated in several of our ancient records, but it did not form a fair criterion of the value of gold and silver for two reasons: first, wheat in those days was less the food of the lower, and even of the middle classes, than rye or barley; and, secondly, at a time when there were few storehouses for corn, little disposable capital to invest in it, and wretched roads to take it to market, the plenty in one part of the Country could not be made to relieve the scarcity in another. Hence the price of wheat differed greatly from year to year, and in separate districts. These facts are useful in estimating the value of silver in the Middle Ages. They tend to confirm the opinion of the late Arthur Young, that the average price of wheat in England during the XIIIth, XIVth, and XVth Centuries was not below a fifth of its present price, or 10*s.* a quarter. Labour, in like manner, was

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paid in those days with silver and copper in very small sums; but if to these we add the value of maintenance, which was almost always supplied to the labourer, we find that his remuneration was not so trifling as is commonly thought. Allowance also is to be made for the general inferiority of the workmen and of the articles sold in so rude an era, particularly manufactures, which with the exception of a few, such as woollens and leather, were nearly as dear as in subsequent periods of our History. The result seems to be that in the XIIIth, XIVth, and XVth Centuries in England, and as far as we know in Europe generally, the value of silver may be stated in the proportion of one to three, when compared with its present value: £100 in those days being equal, in the power of purchasing the various requisites of housekeeping, to £300 at present, and not to more.

The American mines.

We now come to a remarkable epoch in the production of the precious metals, the occupation of Mexico and Peru by the Spaniards. The supply of gold and silver obtained from the Western hemisphere during thirty years after its discovery, was wholly insignificant. Hispaniola, the only important Country then occupied by the Spaniards, was quite unimportant as a seat of mines. But in the year 1521, Cortez invaded Mexico, and occupied the Capital, together with most of the inhabited districts. After this event, the supply of silver from America to Europe increased to half a million sterling a year; an amount trifling according to our present ideas, but by no means so in an Age when so small a portion of the Public could afford to use silver plate, and when, consequently, almost all the silver that was imported was added to the money in circulation. In the course of thirty years, the effect on prices in England, from this and other causes, was very remarkable. "My father," said Bishop Latimer, when preaching in 1548 before his young Sovereign Edward VI., "my father rented forty years ago a farm at six pounds a year. He kept hospitality for his neighbours; he gave alms to the poor; but he that now has the same farm pays fourteen pounds of yearly rent, and is consequently unable to do any thing for his Prince, his children, or the poor." Other causes, doubtless, had a share in this rise of rent; but it is remarkable, that about the time this Discourse was delivered, the discovery of the rich mine of Potosi in Peru took place, after which the import of silver from America to Europe proceeded in an augmented ratio; at the rate, it is calculated, of two millions sterling a year. To this chiefly is attributed the rise of prices which continued during almost the whole of the long reign of Elizabeth, towards the close of which most articles cost nearly twice as much as forty or fifty years before.

Produce of the American mines from 1600 to 1700.

The mines of Potosi yielded considerable produce during the early part of this Century, but fell off towards its close; new mines, however, were opened in Peru and in the vast inland tract between that Country and La Plata. But the chief increase was in Mexico, and from the mines now held by London Companies, but which from causes, which shall be explained forthwith, have as yet proved unprofitable in their hands.

From 1700 to 1810.

During the XVIIIth Century the produce of the American mines experienced a great increase, particularly in Mexico. Quicksilver had now become cheaper, and rude as was the method of extracting the silver from the ore, the abundance of the latter was such as to afford a large return. From Peru also the supply of silver was large, particularly from the mines of Pasco, the object of so unfortunate a speculation by a London Company in the year 1825. Adding to all these the gold obtained in Brazil, the result was that, during the XVIIIth Century, America yielded on an average precious metals to the amount of six or seven millions sterling a year.

Reduced produce since 1810.

The insurrection of 1810 in Mexico was followed by a Civil war, by the destruction of part of the machinery employed on the mines, and some time after by the abandonment of a number of mining establishments. The effect of these disorders has been to reduce an annual produce of seven millions of silver to half that quantity; and as the mines in Europe have merely kept up their very limited supply, the consequence has been a decrease in the amount of coin in circulation throughout the civilized World of more than sixty millions sterling in the last twenty years, or more than three millions on an average annually.

Its effect on the circulating medium.

This decrease has taken place as follows. The quantity of gold and silver required for plate, watches, and ornamental manufacture is very large; probably not less than to the value of six millions sterling yearly. To this is to be added a loss by the wear of coin, by shipwreck, and other accidental causes to the amount of one million annually. To India, China, and other parts of the East, the annual transmission of silver from America and Europe, though less great than formerly, still amounts to nearly two millions, making in all a demand on the mines of eight or nine millions each year. And as the average produce of the mines in the last twenty years has been only five millions, there has been an annual deficiency of three or four millions sterling.

Aggravated by the reduction of paper currency.

But the actual deficiency has been considerably more, for gold and silver have been required in large quantities by several Countries, particularly England and Austria, to replace the paper-money that has been called in. At the general Peace of 1815, Austria had in circulation about a hundred millions sterling of Government paper; but as it was greatly depreciated, the Government considered itself justified in requiring it to be exchanged for paper payable in cash on demand, giving of the latter twenty florins, or two pounds sterling, for every fifty florins, or five pounds of the former. This operation absorbed gold and silver to the amount probably of twenty millions sterling. In England the absorption of specie has been still greater; the necessity imposed on our Banks of paying in cash on demand, and the subsequent replacing of the small notes by sovereigns, must have required the appropriation of specie (chiefly gold) to the amount of nearly twenty-five millions sterling. Add to these for the further sums required in the United States of America, in Russia, and other parts of Europe, a computed amount of fifteen millions, and we shall have a total of sixty millions sterling in gold and silver required to replace Bank or Government paper. The deficiency in the supply from the mines being to the same amount, the total difference between 1810 and the present time is no less than one hundred and twenty millions sterling; that is if four hundred and twenty millions sterling formed the currency of the civilized World twenty years ago, that sum is now reduced to three hundred millions.

So great a decrease would have been quite ruinous to trade, had not this Country and Europe happily continued at peace; there are now no demands for the military chests of armies, and not much for hoarding by timid individuals. Improved means of conveyance now transport gold and silver in a very few days from one

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Capital in Europe to another; from London to Paris; from Paris to Vienna; from Amsterdam to Hamburgh; from Hamburgh to Berlin. By these means a given sum, such as £100,000 in gold, is made to perform certain exchange operations which might have required twice or thrice the amount in time of War. And fortunate it is for the interests of Commerce that it should be so; for the great and general increase of population, and the equally great increase of commodities requiring an augmented supply of money to circulate them, would otherwise have greatly aggravated the distress arising from the diminished stock of the precious metals.

English Companies connected with Mexico.

It was in 1824 that several Associations or Companies were formed in London to put the mining works again in a state of activity. They obtained leases of the principal mines, provided large capitals, and sent out to Mexico agents, machinery, and mining workmen. The efforts of these Companies have as yet been unsuccessful, owing chiefly to the following causes:

1. The mines were dilapidated to a much greater degree than was expected, and required very expensive repairs.

2. There being no silver mines in England, the agents and workmen sent out were, and still are, unacquainted with the proper processes, particularly for separating the silver from the ore. They follow the rude practice of the Mexicans, with very little attention to the improved methods which have been in course of adoption in Germany during the last thirty or forty years.

3. Mining, like all undertakings of difficulty in Mexico, had been managed by natives of Spain, the Mexicans having neither the information nor the activity required for such enterprises. But the Civil war having ended in favour of the Mexicans, the Spaniards were obliged to leave the Country, which was thus deprived of their capital, and of what it could equally ill afford, their intelligence and habits of business.

In the absence of Spaniards, the English arriving at the mines had recourse to the natives, who being ignorant of Mechanics, Chemistry, and the principles of mining, proved most incompetent assistants. They had, in nine cases out of ten, no other object than to cause as much English capital as possible to circulate amongst them. Hence the absorption of the chief part of the funds of the Companies in a very few years.

Prospect of the Mexi-

Such have been the causes of the failure hitherto of the Mining Associations; but what, it may be asked, is the prospect for the future? First, the mines of Mexico are very numerous, those that are exhausted bearing but a small proportion to those that continue productive. The ore is abundant but not rich: hence the necessity of employing many thousand workmen. In fact, the great extent to which mining has been carried in Mexico, compared to Peru and other Provinces of Spanish America, has been owing to a very simple cause, the greater supply of labourers. In Peru the population is chiefly in valleys, while the mines are in mountains, the keen air of which is highly pernicious to the workmen from the plains; but in Mexico, a continued table-land, the temperature is nearly the same througnout. The labourers employed at the mines have consequently good health, and progressively increase their numbers, like the miners in Cornwall and in Saxony.

It thus appears that the arguments in favour of a prospective increased supply of silver, are

The abundance of ore in the mines;

The increasing number of mining workmen;

And, on the assumption of continued Peace, a further supply of capital from England to work the mines.

On the other side of the question are:

The unacquaintance of our miners with silver ore;

The general ignorance of the Mexicans, and

The very slow progress of the Companies in correcting the defects of their present system.

It is well known that in any Country, Joint Stock Companies succeed only when the agency of their servants is confined to a few plain objects, and when all that admits of being delegated, is transferred to individuals acting on their own account. Thus at most of the mines in Europe the practice is to sell the ores as soon as they are raised to the surface, leaving to individuals the nice and difficult task of reducing the ores, or separating the silver from the dross. But in Mexico that practice is by no means general; several of the mining districts are as yet too poor and too thinly peopled to supply persons qualified to reduce the ores; and there are considerable difficulties in bringing such persons from Europe and settling them at the mines.

It is thus almost impossible to calculate with confidence the future produce of the Mexican mines, but a large increase is certainly not to be expected at present. And it is a Historical fact of great importance, that at no period during the last two hundred years has the supply of silver from America had much effect in raising prices in Europe; it has done little more than keep them at the scale they attained in the XVIth Century. Although the influx of silver was regularly on the increase, the consumption of it extended in nearly an equal proportion. The causes are, that of the silver raised annually from mines, only a third part is converted into coin, while two-thirds are used for plate, and other purposes of ornament. The demand for silver thus increases with the population and wealth of the civilized World; these have advanced continually during the last two centuries, and at no period has there been a greater prospect of their further increase than at present.

It follows, therefore, that an augmented supply of silver would be readily absorbed by the demands of the civilized World; and that there is at present no prospect of any such increase as would cause a rise in the price of commodities.

Commercial Prospects of England.

Merchants strictly practical in their habits.

While few departments of industry have been followed in practice to so great an extent as Commerce, hardly any has been less an object of study in regard to its principles. The habits of merchants are strictly practical, and when they act by rule, even the most judicious among them are unconscious that they do so, because such rules exist only in the mind of the individual, being the result not of study or of the lessons of others, but of his personal experience during a number of years. Many merchants are remarked as well for intelligence and reflection, as for extensive information; but as that information is not reduced into a system, and is brought forth only in occasional conversation, it expires, in a great measure, with the possessor; so that new generations are left to acquire experience, like their predecessors, by length of time and practice in business. Readily do we admit that practice and intercourse are as indispensable in forming a merchant as a lawyer or physician, but they do not

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supersede instruction by principle any more in trade than in law or medicine. Like these professions, Commerce has its general rules; its precepts affirmative and negative. Supported by the former, the merchant will persevere in an occupation or a connection which temporary disappointments might otherwise make him abandon: deterred by the latter, he will avoid those tempting but fallacious undertakings in which his unthinking brethren are so ready to engage.

Errors from their deficient information.

The most effectual mode of proof is by example, and if we look for a case of suffering on the part of our merchants, from their being merely practical men, we shall find it unfortunately too soon: we need go no further than seven or eight years back, when the trade of Mexico and the rest of Spanish America was opened to this Country. Aware that quantities of gold and silver had for many Ages been supplied by those Countries, our merchants considered them wealthy in other respects, and entitled to large credits, as well for the manufactures they bought from us, as for the money which their respective Governments proposed to borrow. Hence arose large exports of our merchandise, followed by extensive loans on the faith of South American funds, and equally extensive advances on the security of their mines. We will not dwell on the amount of the loss thus incurred; on the millions thus transferred from England to the Western Hemisphere: the point is to consider whether the mania would have been carried so far had our merchants had the benefit of instruction in the Principles of Commerce. In the course of such instruction one of the earliest lessons would have been, that Countries producing gold and silver are in general poor: that mines of those metals do not, any more than mines of coal, or iron, or copper, offer their treasures on easy terms, but must be wrought with great labour, and under careful superintendence. The expense of mining is in general such as to restrict the profit on it to the same limited scale as the profit on agriculture or manufactures. Another important lesson derived from studying the History of Commerce is, that thinly peopled Countries, like Spanish America, are invariably bare of capital, whatever be their advantages as to soil and climate. The reasons are obvious: capital is a plant of slow growth, the result of skill, labour, and perseverance; advantages to be found only in populous and long settled communities. Holland, with a marshy soil and an uninviting climate, has long proved a valuable customer for our manufactures, because the amount of her population and the advanced state of their productive industry, enable her to supply us in return either with valuable commodities or with money arising from the sale of such commodities. But a region like Spanish America, which, compared to England, has not on the same extent one inhabitant to twenty, can have no wealth arising from manufactures, and not much arising from Country products. Of all such products, whether the indigo, sugar, and cotton of a tropical climate, or the corn and wines of more temperate regions, the main constituent is labour, and labour can never be abundant where the population is scanty. Simple as are these truths, a knowledge of them on the part of our mercantile Countrymen in the unfortunate year 1825, would have been the means of saving many millions to England.

The year 1825. Mexico.

Poverty of mining districts.

and of all thinly peopled Countries.

Our next example of miscalculation as to Commerce shall be of quite a different nature, and taken from the conduct of our Government in the last Century. It is now sixty years since the origin of our differences with our North American Colonies which burst forth into open war in 1775, and ended, after a seven years' struggle, in their separation from the Mother Country. Those Colonies had long been bound by Acts of Parliament to take their manufactures from England, and to send all their exported produce, their tobacco, their flour, their timber, to this Country in the first instance; that we might purchase as much as was wanted for our use, and have a profit on the sale of the remainder to foreigners. These restrictions seemed to our Statesmen, as to our merchants, of great advantage to the Mother Country. The war with the Colonies was of long continuance, and many persons in England lamented it, but they did so chiefly on considerations of humanity. No speaker in Parliament, no practical merchant, came forward to maintain that we should be able to retain our trade with the Americans without the aid of monopoly, England being the only Country in Europe that could afford the long credit rendered necessary by their scanty capital. Peace came in 1783, and our Countrymen were prepared to resign a great part of this trade, when to their surprise they found it not only continue but increase. Could political feeling have decided the question the result would have been different. The national attachment of the Americans was to the French. They had fought together against us; they had a mutual jealousy of our naval power; they were eager to draw closer their connection by the ties of commercial intercourse; but all was unavailing. Then, as at present, France was bare of capital, and not rich in manufactures; she could supply America only with wines and silk; the other great articles of consumption, woollens, linen, cotton, hardware, continued to be drawn from England. The result has been, that from America separated, or, as she styled herself, independent, we have reaped much more advantage than from the same Country when subject to our colonial laws. How much blood and treasure would have been saved had our Statesmen and our merchants been earlier aware of this truth; and had they known that the chief subject for their consideration was merely whether our Colonists were sufficiently advanced in political science to conduct their own Government. If they were so, it was clearly for the mutual advantage of Countries so distant from each other, to separate, each confining itself to the administration of its own affairs.

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War with the North Americans in 1775; its causes.

But of all examples of error arising from deficient knowledge of the principles of trade, the most striking was afforded during our late Wars with France. Ministers, merchants, Members of Parliament, were all deceived by appearances; all joined in believing that the impoverishing effect of former Wars was completely belied by our situation, Commercial and Financial, during that long contest. Money seemed every year to increase in abundance; the country gentleman receiving augmented rents for his farms; the town landlord for his houses; the manufacturer a higher price for his woollens, his linens, his hardware; while the humble mechanic, and the still humbler country labourer, experienced a progressive increase in their wages. So general a rise in the scale of payments could, in the general opinion, proceed only from increased wealth, and that wealth must, according to the mercantile creed, be obtained at the expense of our neighbours. Of this we had an amusing example in the writings of the late Arthur Young. "The French Revolution," he said, "burst forth like a volcano, laying the industry,

Wars of the French Revolution: financial miscalculations.

manufactures, and Commerce of France, and eventually those of the whole Continent, in the dust. Britain became the emporium of the World, and such a scene of wealth and prosperity filled every eye in this happy Country as the Sun before had never shone upon."

Such was the general opinion of our merchants, and as to the cause of any great change, practical men seldom go far for a solution; our navy was unresisted on the ocean, and our mercantile shipping had increased; hence a common belief that our augmented wealth arose from foreign trade. Even men the least connected with Government, had no distinct idea of the temporary nature of our prosperity or of the probability of a reaction. Not that we were without examples in History of such a reaction; for Sir William Temple, in his interesting account of the trade of Holland in the XVIIth Century, had described, in a manner equally clear and impressive, the general stagnation in mercantile affairs which followed the Peace of Westphalia. A similar fall of prices took place after the Peace of Utrecht in 1712, and, in some degree, after our Peace with France, Spain, and the United States of America, in 1783. But of these latter changes there was no clear or satisfactory record, and, unfortunately, before the close of the last War, we had lost in Pitt the only Minister familiar with such a transition, the only one who, during the excitement of the War, had warned his colleagues of the reaction to be apprehended at a Peace. Serious, indeed, has that reaction proved; in point of time it has lasted nearly twenty years, while as to degree, it has, in very many cases, amounted to half the income of whole classes of the community.

Yet, long as has been the period of suffering, the Public are not, even at present, agreed as to its causes. By some it is ascribed to the free-trade system and the competition of foreigners; by others, and a very numerous body, to the resumption of cash payments; while a third party attribute it mainly to the decreased produce of the silver mines of America during the last twenty years. Each of these causes has, doubtless, contributed to the fall of prices, but they are insufficient to account for so great and general a result: for this fall has taken place in France, Italy, Germany, Countries in which Banks are almost unknown, and where, consequently, there were no small notes to be called in. It must

Causes of the decline of price

[be] owing, therefore, to causes of very comprehensive operation, and what so likely to hold the first rank in the list as the change from general War to general Peace: a change which gave back so many millions of capital, and so many hundred thousand hands to productive employment; which renewed the intercourse between all Countries, substituting open and unrestricted trade for the barbarous anti-commercial edicts of Bonaparte. If, in proof of this, we select any particular class of Society, we shall find that the decline of prices since the Peace has borne a remarkable proportion, both in its nature and degree, to their rise during the War; those who profited most during the contest having, in general, been the most reduced since the Peace. This holds in regard to most of the productive classes, or those who earn their support chiefly by personal exertion, and the employment of a limited capital. Of this description are farmers, and the very numerous Body, who, whether agriculturists, traders, or professional men, carry on their business with borrowed money. All these classes find the payment of their rent, interest, and other fixed money charges, much more heavy since the fall in the price of the commodities in which they respectively deal; involving as it does a decrease in the wages, salaries, and professional fees, which form their respective incomes. But that is not all: a similar decline has taken place in the value of their fixed capital, such as stock in trade, machinery, or buildings. Cramped thus in their power of employing the lower orders, a number of the latter are thrown out of work. We hear, year after year, of a superabundance of country labourers, owing not to there being more labourers than are required to raise the requisite supply of provisions, for of late years we have imported corn largely, but to the reduced capital of our farmers, which prevents them from giving employment to those who want it.

From how many classes of the community do we hear similar complaints? From the manufacturers of woollens, cottons, linen, and more pointedly still from ship-builders, and the iron and hardware merchants. One important part of our national property, houses, long maintained a high rent in consequence chiefly of our increasing population; but of late that property also has fallen. How easily might we continue this painful catalogue, this enumeration of losses and embarrassments consequent on the lavish use of paper money during the War. How clearly could all this be traced to a deficient knowledge of the Principles of Commerce and finance; but we will not dwell on past errors: we will turn to a more cheering theme; to the prospect of surmounting our distress and the means by which it is to be attempted.

Prospect of relief: our resources increasing.

Amidst all these embarrassments and complaints, there is evidently no falling off in the productive powers of the Country. The quantity of our yearly crops, the extent of our manufactures, the amount of our mercantile shipping are all greater than at any former time, and all in a state of progressive increase. It follows, then, that the real wealth of the Country continues in an augmenting ratio; the pressure on us arises from the evils of transition; from unfortunate fluctuations in our currency; from the prices of very many articles, whether of produce or manufacture, having fallen in a greater degree than the charge of preparing and bringing them to market. Now such a disproportion cannot continue; if we are not able to foresee in what manner or after what lapse of time the equilibrium will be restored, we may safely assume that restored it will be, because the existing insufficiency of price is as contrary to fairness and justice, as its long continuance would be contrary to all experience.

Our agricultural produce.

First, as to our annual growth of corn and other country produce. During the War, considerable uneasiness was felt by the Public at the insufficiency of our crops and at our consequent dependence on foreigners. "Provisions," it was said, "will rise in price, and our manufacturers will go to cheaper Countries. The corn-exporting part of Europe may, it was added, again fall under the sway of a madman like Paul of Russia, or of a headstrong despot like Bonaparte; in times of scarcity the consequences might be most injurious." But from such an apprehension we are now almost wholly relieved: the quantity of our yearly produce is increased; agricultural improvements are extending in Ireland, in Canada, and on the shores of the Euxine; Countries too remote from each other to be controuled by any single power. Sixty years ago it was a common notion that the English raised as much produce, and prepared as

Commerce.

much of manufactures as the limited extent of our territory admitted; and a French Political Economist, the father of the well-known Mirabeau, told his Countrymen in a printed Work: "You have been outstripped in the career of productive industry by the English, but do not apprehend that they will continue to take the lead, for they have advanced as far as it is possible for them to go." Yet, at that time our annual crops were not half their present amount; our mercantile tonnage not one-third; our export of manufactures not much above a fourth of the present quantity! So much for the accuracy of this foreigner: among ourselves, a well-known writer on population long since sounded the alarm at our increasing numbers; while one of his antagonists, writing twenty years ago, comforted us with the assurance that we might be tranquil until our average numbers should amount to three hundred persons on a square mile. To that limit we are now fast approaching, the census of 1831 exhibiting about two hundred and seventy persons in England to the square mile; yet our farmers supply the augmented number with provisions as easily as their fathers and grandfathers supplied half the number in a former Age. The truth is, that we are wholly unable to fix a limit to the productive powers of a Country; Ireland, the most densely peopled part of the United Kingdom, which at present supports eight millions of inhabitants, may, under an improved system of agriculture, so add to her produce, as, at no remote date, to support, perhaps, twice her present numbers, and to send to England twice or three times as much wheat and oats as at present. We may, therefore, safely dismiss the apprehension of our manufacturers taking up their residence in cheaper Countries: at present provisions are not dearer in England than on the Continent by so much as a fifth or twenty per cent.; and there is great reason to think that the difference will become progressively less.

Ireland.

Our manufacturers not likely to go abroad.

But whatever disadvantage our workmen may labour under in regard to provisions, is balanced, and more than balanced by the cheapness of the other constituents of manufacturing prosperity, such as coal, iron, roads, canals, railways. In coal we have an unquestioned superiority, both as to the quality of the mineral and the means of conveying it. Coal is found in various parts of the interior of Europe; in Poland, in Austria, in Spain; but how limited are the means of transporting it, and how long the time that must elapse ere those poor and thinly peopled Countries will be able to make the canals and railways required for that purpose! The same holds in regard to iron, our mines of which were hardly known forty years ago, when we were content to look to Sweden for the supply of an article, of which we now make above 600,000 tons annually. As to canals, it is now about seventy years since they began to be excavated in England; that is, since the intercourse between our chief towns became such as to defray a mode of transport which in the outset is very costly. Now, on the Continent of Europe, canal communication is extensive only in the Netherlands; in France, much as it has been spoken of, it is still on a very limited scale; while in Italy, Germany, Spain, the canals are absolutely insignificant. It follows that most of the improvements effected in this Country at so heavy an expense, remain to be made on the part of the nations attempting to rival us; and with how inferior means on their part as to capital and machinery!

Superiority of England, in roads, canals, coal, iron.

Equally inferior are their means as far as such depend on the distribution of their population; with them the majority of the inhabitants reside in the country; with us they reside in towns. Take the twelve principal towns of France, and compare the number of their inhabitants with that of the twelve principal towns of England and Scotland, and in the case of each of the places compared, the superiority of numbers will be found on our side. Again, take the whole town population of France, and extensive as that Country is, the aggregate of the inhabitants of her towns will not be found to equal in number the town population of Great Britain and Ireland. In England, so improved is our agriculture, so important are the advantages arising from farming capital, from better implements, from subdivision of work, that thirty-three persons in one hundred are sufficient to raise provisions for the community at large; while in France the labour of fully fifty persons in one hundred is required for that purpose. How great is the superiority of workmen collected in towns over a scattered peasantry! how steady their continuance at one kind of employment! how exact their execution! Their better wages enable them to consume much more of taxed commodities; hence the large revenue of Holland a century and half ago, at a time when in the rest of Europe the names of Excise and Customs were hardly known: hence at present the payment in this Country by duties on consumption of twice as much revenue as in France. To whatever part of Commercial History we look, whether to ancient or modern times, to Egypt, Phœnicia, Greece, Carthage; to Modern Italy, the Netherlands, or the Hanse Towns, we find increase of town population the cause and accompaniment of augmented wealth. Nor is there any reason to question that we shall keep up and increase our superiority in this respect. The difference of expense between town and country is less in England than on the Continent, because the extent of our communications both by sea and land facilitate the transport of corn, fuel, timber, and other bulky commodities, and cause an approach to equality in most parts of the Kingdom. The improvements now in progress in our turnpike roads and railways bid fair to lessen further the cost of provisions in towns, and greatly to augment the number of their inhabitants.

In town population.

Enough has now been stated to show how little we have to apprehend from the competition of foreigners. In our internal regulations, our laws relating to trade, Banking, and taxes, so far as the latter affect trade, our present sufferings are caused in a considerable degree by mistaken Legislation; by abuses allowed to remain on the Statute book on little other ground but that of prescription. This, however, is not the place, nor indeed, if it were so, have we either room or inclination to enter upon the dangerous and difficult review by which this subject must be illustrated. It may suffice to express our hope, that a time has now arrived in which the narrowness of private opinion will be superseded by a more expansive general reasoning, and in which Mercantile interests will be regulated not by caprice, accident, or prejudice, but by the more sure and enlightened guidance of a study of THE PRINCIPLES OF COMMERCE.

Internal regulations.

POLITICAL ECONOMY.

Definition of the Science.

Definition of the Science.

We propose in the following Treatise to give an outline of the Science which treats of the nature, the production, and the distribution of wealth. To that Science we give the name of Political Economy. Our readers must be aware that that term has often been used in a much wider sense. The earlier writers who assumed the name of Political Economists avowedly treated not of wealth but of government. Mercier de la Riviere entitled his Work *The Natural and Essential Organization of Society*, and professed to propose an organization "which shall necessarily produce all the happiness that can be enjoyed on earth."* Sir James Steuart states, that "the principal object of the Science is to secure a certain fund of subsistence for all the inhabitants, to obviate every circumstance which may render it precarious, and to provide every thing necessary for supplying the wants of the society."† The modern continental writers have in general entered into an equally extensive inquiry. "Political Economy," says M. Storch, "is the Science of the natural laws which determine the prosperity of nations, that is to say, their wealth and their civilization."‡ M. Sismondi considers "the physical welfare of man, so far as it can be the work of government, as the object of Political Economy."§ "Political Economy," says M. Say, "is the economy of society; a Science combining the results of our observations on the nature and functions of the different parts of the social body."‖ The modern writers of the English school have in general professed to limit their attention to the theory of wealth; but some of the most eminent among them, after having expressed their intention to confine themselves within what appears to us to be their proper province, have invaded that of the general legislator or the statesman. Thus Mr. M'Culloch, after having defined Political Economy to be "the Science of the laws which regulate the production, accumulation, distribution, and consumption of those articles or products that are necessarily useful or agreeable to man, and possess exchangeable value;"¶ or, "the Science of values;" adds, that "its object is to point out the means by which the industry of man may be rendered most productive of wealth, to ascertain the circumstances most favourable to its accumulation, the proportions in which it is divided, and the mode in which it may be most advantageously consumed."**

It is impossible to overstate the importance of these inquiries, and it is not easy to state their extent. They involve, as their general premises, the consideration of the whole theory of morals, of government, and of civil and criminal legislation; and, for their particular premises, a knowledge of all the facts which affect the social condition of every community whose conduct the Economist proposes to influence. We believe that such inquiries far exceed the bounds of any single Treatise, and indeed the powers of any single mind. We believe that by confining our own and the reader's attention to the nature, production, and distribution of wealth, we shall produce a more clear, and complete, and instructive work than if we allowed ourselves to wander into the more interesting and more important, but far less definite, fields by which the comparatively narrow path of Political Economy is surrounded. The questions, to what extent and under what circumstances the possession of wealth is, on the whole, beneficial or injurious to its possessor, or to the society of which he is a member? what distribution of wealth is most desirable in each different state of society? and what are the means by which any given Country can facilitate such a distribution?—all these are questions of great interest and difficulty, but no more form part of the Science of Political Economy, in the sense in which we use that term, than Navigation forms part of the Science of Astronomy. The principles supplied by Political Economy are indeed necessary elements in their solution, but they are not the only or even the most important elements. The writer who pursues such investigations is in fact engaged on the great Science of legislation; a Science which requires a knowledge of the general principles supplied by Political Economy, but differs from it essentially in its subject, its premises, and its conclusions. The subject of legislation is not wealth, but human welfare. Its premises are drawn from an infinite variety of phenomena, supported by evidence of every degree of strength, and authorizing conclusions deserving every degree of assent, from perfect confidence to bare suspicion. And its expounder is enabled, and even required, not merely to state certain general facts, but to urge the adoption or rejection of actual measures or trains of action.

Limits of the Science

On the other hand, the subject treated by the Political Economist, using that term in the limited sense in which we apply it, is not happiness, but wealth; his premises consist of a very few general propositions, the result of observation, or consciousness, and scarcely requiring proof, or even formal statement, which almost every man, as soon as he hears them, admits as familiar to his thoughts, or at least as included in his previous knowledge; and his inferences are nearly as general, and, if he has reasoned correctly, as certain, as his premises. Those which relate to the nature and the production of wealth are universally true; and though those which relate to the distribution of wealth are liable to be affected by the peculiar institutions of particular Countries, in the cases for instance of slavery, legal monopolies, or poor laws, the natural state of things can be laid down as the general rule, and the anomalies produced by particular disturbing causes can be afterwards accounted for. But his conclusions, whatever be their generality and their truth, do not authorize him in adding a single syllable of

* *Discours Préliminaire*, liv. vi.
† Vol. i. p. 2.
‡ Tom. i. p. 21.
§ *Nouveaux Principes d'Economie Politique*, liv. i. ch. ii.
‖ *Cours Complet*, tom. i. p. 1, 2.
¶ *Principles, &c.* p. 1.
** *Ibid.* p. 8

Political Economy.

Limits of the Science.

advice. That privilege belongs to the writer or the statesman who has considered all the causes which may promote or impede the general welfare of those whom he addresses, not to the theorist who has considered only one, though among the most important, of those causes. The business of a Political Economist is neither to recommend nor to dissuade, but to state general principles, which it is fatal to neglect, but neither advisable, nor perhaps practicable, to use as the sole, or even the principal, guides in the actual conduct of affairs. In the mean time the duty of each individual writer is clear. Employed as he is upon a Science in which error, or even ignorance, may be productive of such intense and such extensive mischief, he is bound, like a juryman, to give deliverance true according to the evidence, and to allow neither sympathy with indigence, nor disgust at profusion or at avarice—neither reverence for existing institutions, nor detestation of existing abuses—neither love of popularity, nor of paradox, nor of system, to deter him from stating what he believes to be the facts, or from drawing from those facts what appear to him to be the legitimate conclusions. To decide in each case how far those conclusions are to be acted upon belongs to the art of government, an art to which Political Economy is only one of many subservient Sciences; which involves the consideration of motives, of which the desire for wealth is only one among many, and aims at objects to which the possession of wealth is only a subordinate means.

The confounding Political Economy with the Sciences and Arts to which it is subservient has been one of the principal obstacles to its improvement. It has acted thus in two different modes:—

First, by exciting in the public unfavourable prejudices.

And, secondly, by misleading Economists, both with respect to the object of their Science and the means of attaining it.

With respect to the first of these obstacles, it has often been made a matter of grave complaint against Political Economists, that they confine their attention to wealth, and disregard all consideration of happiness or virtue. It is to be wished that this complaint were better founded, but its general existence implies an opinion that it is the business of Political Economists not merely to state propositions, but to recommend actual measures, for on no other supposition could they be blamed for confining their attention to a single subject. No one blames a writer upon tactics for confining his attention to military affairs, or, from his doing so, infers that he recommends perpetual war. It must be admitted that an author who, having stated that a given conduct is productive of wealth, should, on that account alone, recommend it, or assume that, on that account alone, it ought to be pursued, would be guilty of the absurdity of implying that happiness and the possession of wealth are identical. But his error would consist not in confining his attention to wealth, but in confounding wealth with happiness. Supposing that error, and it is a very obvious one, to be avoided, the more strictly a writer confines his attention to his own Science, the more likely he is to extend its bounds.

Secondly, the confounding the Science of Political Economy with the Sciences and Arts to which it is subservient, has seduced Economists sometimes to undertake inquiries too vague to lead to any practical results, and sometimes to pursue the legitimate objects of the Science by means unfit for their attainment. To their extended view of the objects of Political Economy is to be attributed the undue importance which many Economists have ascribed to the collection of facts, and their neglect of the far more important process of reasoning accurately from the facts before them. We are constantly told that it is a Science of facts and experiment, a Science *avide de faits*. The practical applications of it, like the practical applications of every other Science, without doubt, require the collection and examination of facts to an almost indefinite extent. The facts collected as materials for the amendment of the poor-laws, and the opening of the trade to China, fill more than twice as many volumes as could be occupied by all the Treatises that have ever been written on Political Economy; but the facts on which the general principles of the Science rest may be stated in a very few sentences, and indeed in a very few words. But that the reasoning from these facts, the drawing from them correct conclusions, is a matter of great difficulty, may be inferred from the imperfect state in which the Science is now found after it has been so long and so intensely studied.

This difficulty arises partly from the extremely complicated nature of the subjects which it investigates, and the consequent abstractness and generality of its terms. A description, if it were possible, of all the different things which are designated by the word "wealth," or even by the less comprehensive word "capital," would fill an Encyclopædia. It arises partly, also, from the circumstance, that the terms which we are forced to use as signs for these abstractions are taken from ordinary language, commonly used in senses too wide or too narrow for scientific purposes. In the case, therefore, both of the writer and of the reader, they are often associated with ideas which are intended to be excluded, or separated from ideas which are meant to be comprehended. Thus, in ordinary language, the word capital is sometimes used as comprehending every species of wealth, and sometimes as confined to money.

If Economists had been aware that the Science depends more on reasoning than on observation, and that its principal difficulty consists not in the ascertainment of its facts, but in the use of its terms, we cannot doubt that their principal efforts would have been directed to the selection and consistent use of an accurate nomenclature. So far is this from having been the case, that it is only within a very short period that serious attention has been given to its nomenclature. *The Wealth of Nations* contains scarcely a definition: most of the modern French writers, and some indeed of our own, have not only neglected definitions, but have expressly reprobated their use; and the English Work which has attracted the most attention during the present century, Mr. Ricardo's *Principles of Political Economy*, is deformed by a use of words so unexplained, and yet so remote from ordinary usage, and from that of other writers on the same subject, and frequently so inconsistent, as to perplex every reader, and not unfrequently to have misled the eminent writer himself. We do not complain of all his innovations in language: such innovations are, for scientific purposes, frequently indispensable, and we shall be forced to make many ourselves. What we do complain of is, that his innovations, such, for instance, as the substitution of the word *value* for *cost*, are frequently unnecessary, and are almost always made without any warning to his readers; and that the same words, such, for example, as the adjectives *high*

and *low*, when applied to wages, are used by him sometimes in their popular sense, as expressing an amount, and sometimes in a technical sense of his own, as expressing a proportion.

Our object in these remarks has been not only to account for the slow progress which has as yet been made by Political Economy, and to suggest means by which its advancement may be accelerated, but also to warn the reader of the nature of the following Treatise. He will find it consist, in a great degree, of discussions as to the most convenient use of a few familiar words. Such discussions it is impossible to render amusing, but we trust that they will be useful, by directing his attention to the great difficulties of the Science, though he may often disapprove our classification or nomenclature.

Wealth.

Wealth.

Having stated that the Science which we propose to consider, and to which we apply the term Political Economy, is the Science which treats of the nature, the production, and the distribution of wealth, our first business is to explain the meaning in which we use the word wealth.

Under that term we comprehend all those things, and those things only, which are transferable, are limited in supply, and are directly or indirectly productive of pleasure or preventive of pain; or, to use an equivalent expression, which are susceptible of *exchange;* (using the word exchange to denote hiring as well as absolute purchase;) or, to use a third equivalent expression, which have *value;* a word which, in a subsequent portion of this Treatise, we shall explain at some length, merely premising at present that we use it in its popular sense, as denoting the capacity of being given and received in exchange.

Of the three qualities which render any thing an article of wealth, or, in other words, give it value, the most striking is the power, direct or indirect, of producing pleasure, including under that term gratification of every kind, or of preventing pain, including under that term every species of discomfort. Unfortunately, we have no word which precisely expresses this power; *utility*, which comes nearest to it, being generally used to express the quality of preventing pain or of indirectly producing pleasure, as a means. We shall venture to extend the signification of that word, and consider it as also including all those things which produce pleasure directly. We must admit that this is a considerable innovation in English language. It is, however, sanctioned by Mr. Malthus, (*Definitions*, p. 234,) and has been ventured by M. Say in French, a language less patient of innovation than our own. Feeling the same difficulty, he has solved it in the same way by using the term *utilité* as comprehending every quality that renders any thing an object of desire. Attractiveness and desirableness have both been suggested to us as substitutes, but on the whole they appear to us more objectionable than *utility*, objectionable as we must admit that word to be.

Utility, thus explained, is a necessary constituent of value; no man would give any thing possessing the slightest utility for a thing possessing none; and even an exchange of two useless things would be, on the part of each party to the exchange, an act without a motive. Utility, however, denotes no intrinsic quality in the things which we call useful; it merely expresses their relations to the pains and pleasures of mankind. And, as the susceptibility of pain and pleasure from particular objects is created and modified by causes innumerable, and constantly varying, we find an endless diversity in the relative utility of different objects to different persons, a diversity which is the motive of all exchanges.

Wealth.

The next constituent of value is *limitation in supply*. It may appear inaccurate to apply this expression to any class of things, as it, in fact, belongs to all; there being nothing which, strictly speaking, is unlimited in supply. But, for the purposes of Political Economy, every thing may be considered as unlimited in supply *in its existing state*, of which a man may have as much as he pleases for the mere trouble of taking it into his possession. Thus the water of the open sea is, in our use of the term, unlimited in supply; any man who chooses to go for it may have as much of it as he pleases: that portion of it which has been brought to London is limited in supply, and is to be obtained not merely by going to the reservoir and taking possession of it, but by giving for it an equivalent. The copper ores which Sir John Franklin discovered on the shores of the Arctic Sea may be considered, *in their existing state*, as unlimited in supply; any man may have as much of them as he has strength and patience to extract. The extracted portion would be limited in supply, and therefore susceptible of value. Many things are unlimited in supply for some purposes, and limited for others. The water in a river is in general more than sufficient for all the domestic purposes for which it can be required; nobody pays therefore for permission to take a bucketfull: but it is seldom sufficient for all those who may wish to turn their mills with it; they pay, therefore, for that privilege.

It must be further observed that, for economical purposes, the term *limitation in supply* always involves the consideration of the causes by which the existing supply is limited. The supply of some articles of wealth is limited by insurmountable obstacles. The number of Raphael's pictures, or of Canova's statues, may be diminished, but cannot possibly be increased. There are others of which the supply may be increased to an indefinite extent. Such things may be considered as comparatively limited in supply, in proportion, not to the existing supply of each, but to the force of the obstacles opposed to their respective increase. It is supposed that there is now about forty-five times as much of silver extracted from the mines, and current in Europe, as there is of gold. Human exertion is the only means by which the supply of either can be increased, and they may both be increased by human exertion to an amount of which we do not know the limit. The obstacle, therefore, by which they are each limited in supply is, the amount of human exertion necessary to their respective increase. About sixteen times more exertion is necessary to produce an ounce of gold than an ounce of silver. The obstacle, therefore, which limits the supply of gold is sixteen times more powerful than that which limits the supply of silver. In our sense of the term, therefore, gold is only sixteen times more limited in supply than silver, though the actual weight of silver in Europe is forty-five times as great as that of gold. To take a more familiar example, the number of coats and waistcoats in England is perhaps about equal. The supply of each may be increased by human exertion to an indefinite extent; but it requires about three times as much exertion to produce a coat as to produce a waist-

coat. As the obstacle, therefore, which limits the supply of coats is three times as forcible as that which limits the supply of waistcoats, we consider coats three times more limited in supply than waistcoats, though the existing supply of each may perhaps be equal. Whenever, therefore, we apply the words *limited in supply*, as a comparative expression, to those commodities of which the quantity can be increased, we refer to the comparative force of the obstacles which limit the respective supplies of the objects compared.

The third and last quality which a thing must possess to constitute it an article of wealth, or, in other words, to give it value, is *transferableness*, by which term (we are sorry to say, an unusual one) we mean to express that all or some portion of its powers of giving pleasure, or preventing pain, are capable of being transferred, either absolutely, or for a period. For this purpose it is obvious that it must be capable of appropriation; since no man can give what he cannot refuse. The sources of pleasure and preventives of pain which are absolutely incapable of appropriation are very few. We almost doubt whether there are any, and we are sure that the instances which are usually given are incorrect. "The earth," observes M. Say, *Econ. Pol.* liv. ii. ch. ix. "is not the only material agent with productive power, but it is the only one, or nearly so, that can be appropriated. The water of rivers and of the sea, which supplies us with fish, gives motion to our mills, and supports our vessels, has productive powers. The wind gives us force, and the sun heat, but happily no man can say, 'The wind and the sun belong to me, and I will be paid for their services.'" Now, in fact, air and sunshine are local. This is so obvious that it would be absurd to prove, by serious induction, that some situations have too much wind, and others too little, or that the sun's rays are more powerful productive agents in England than in Melville Island, or in the Tropics than in England. And as the land is every where capable of appropriation, the qualities of climate, which are attributes of that land, must be so too. What gives their principal value to the vineyards of the Côte Rotie, but the warmth of their sun? or to the houses which overlook Hyde Park, but the purity of their air? Rivers and the sea are equally unfortunate illustrations. Many of the rivers of England are not less strictly appropriated, and are far greater sources of wealth, than any equal superficies of land. When M. Say visited Lancashire, he must have found every inch of fall in every stream the subject of lease and purchase. And so far are the services of the sea from being incapable of appropriation, that, during the late war, £60,000 was sometimes paid for a licence to make use of it for a single voyage; and the privilege of fishing in particular parts of it has been the subject of wars and treaties.

The things of which the utility is imperfectly transferable may be divided into two great classes. The first comprises all those material objects which are affected by the peculiar mental associations, or adapted to the peculiar wants, of individuals. A mansion may flatter the pride of its owner as having been the residence of his ancestors, or be endeared to him as the scene of his childhood; or he may have built it in a form which pleases no eye, or laid it out in apartments that suit no habits but his own. Still its substantial powers of affording warmth and shelter will obtain him purchasers or tenants, though they may demand a reduction from the price in consequence of those very qualities which, with him, formed its principal merits. The palace of St. James's is full of comfort and convenience, and would supply a man of large fortune with an excellent residence; but the long suite of apartments within apartments, which is admirably adapted to holding a Court, would be a mere incumbrance to any but a royal personage. Any individual might hire Alnwick or Blenheim, and enjoy their mere beauty and magnificence, perhaps, more than their owners who have been long familiarized to them; but he could never feel the peculiar pleasure which they seem fitted to give to a Percy and a Churchill. There are many things, such as clothes and furniture, which sink in utility in the estimation of every one but their purchaser, from the mere fact of having changed hands. A hat or a table which has just been sent home does not appear to the purchaser less useful than when he saw it in the shop; but if he attempt to resell either, he will find that with the rest of the world it has sunk into the degraded rank of second-hand.

The second class of things imperfectly transferable includes the greater part, perhaps all, of our personal qualities. This classification, which places talents and accomplishments among the articles of wealth, may appear at first sight strange and inconvenient; it certainly is different from that of most Economists. We will therefore venture to illustrate it more fully.

Health, strength, and knowledge, and the other natural and acquired powers of body and mind, appear to us to be articles of wealth, precisely analogous to a residence having some qualities that are universally useful, and others peculiarly adapted to the tastes of its owner. They are limited in supply, and are causes of pleasure and preventives of pain far more effectual than the possession of Alnwick or of Blenheim. A portion of the advantages which arise from them are inseparably annexed to their possessor, like the associations of an hereditary property: another portion, and often a very large one, is as transferable as the palpable convenience of the mansion, or beauty of the gardens. What cannot be transferred are the temporary pleasure which generally accompanies the exercise of any accomplishment, and the habitual satisfaction arising from the consciousness of possessing it. What can be transferred are the beneficial results which follow from its having been employed during the period for which its services have been hired. If an Erskine or a Sugden undertakes my cause, he transfers to me, for that occasion, the use of all his natural and acquired ability. My defence is as well conducted as if I had myself the knowledge and the eloquence of an accomplished advocate. What he cannot transfer is the pleasure which he feels in the exercise of his dexterity; but how small is his pleasure compared to mine, if he succeeds for me! A passenger may envy the activity and intrepidity of the crew; they cannot actually implant in him their strength, or their insensibility to danger; but so far as these qualities are means towards an end, so far as they enable him to perform his voyage with quickness and safety, he enjoys the use of them as fully as if they belonged to himself. A hunter probably feels somewhat the same sort of pleasure in the chase which Erskine felt in court; and this pleasure cannot be transferred any more than his muscles or his lungs; but, so far as his strength, speed, and bottom are means towards the end of enabling his rider to keep up with the hounds, they can be purchased or hired as effectually as his bridle or saddle. In the

greater part of the world a man is as purchasable as a horse. In such Countries the only difference in value between a slave and a brute consists in the degree in which they respectively possess the saleable qualities that we have been considering. If the question whether personal qualities are articles of wealth had been proposed in classical times, it would have appeared too clear for discussion. In Athens, every one would have replied that they, in fact, constituted the whole value of an εμψυχον οργανον. The only differences in this respect between a freeman and a slave are, first, that the freeman sells *himself*, and only for a period, and to a certain extent, the slave may be sold by others, and absolutely; and, secondly, that the personal qualities of the slave are a portion of the wealth of his master; those of the freeman, so far as they can be made the subjects of exchange, are a part of his own wealth. They perish indeed by his death, and may be impaired or destroyed by disease, or rendered valueless by any changes in the customs of the Country which shall destroy the demand for his services; but, subject to these contingencies, they are wealth, and wealth of the most valuable kind. The amount of revenue derived from their exercise in England far exceeds the rental of all the lands in Great Britain.

Of the three conditions of value, utility, transferableness, and limitation in supply, the last is by far the most important. The chief sources of its influence on value are two of the most powerful principles of human nature, the love of variety, and the love of distinction. The mere necessaries of life are few and simple. Potatoes, water, and salt, simple raiment, a blanket, a hut, an iron pot, and the materials of firing, are sufficient to support mere animal existence in this climate: they do, in fact, support the existence of the greater part of the inhabitants of Ireland; and in warmer Countries much less will suffice. But no man is satisfied with so limited a range of enjoyment. His first object is to vary his food; but this desire, though urgent at first, is more easily satisfied than any other, except perhaps that of dress. Our ancestors, long after they had indulged in considerable luxury in other respects, seem to have been contented with a very uniform though grossly abundant diet. And even now, notwithstanding the common declamation on the luxury of the table, we shall find that most persons, including even those whose appetites are not controlled by frugality, confine their principal solid food to but a few articles, and their liquids to still fewer.

The next desire is variety of dress; a taste which has this peculiarity, that, though it is one of the first symptoms that a people is emerging from the brutishness of the lowest savage life, it quickly reaches its highest point, and, in the subsequent progress of refinement, in one sex at least, diminishes until even the highest ranks assume an almost quaker-like simplicity.

Last comes the desire to build, to ornament, and to furnish: tastes which are absolutely insatiable where they exist, and seem to increase with every improvement in civilization. The comforts and conveniences which we now expect in an ordinary lodging are more than were enjoyed by people of opulence a century ago: and even a century ago a respectable tradesman would have been dissatisfied if his bed-room had been no better furnished than that of Henry VIII., which contained, we are told, only a bed, a cupboard of plate, a joint-stool, a pair of andirons, and a small mirror.* And yet Henry was among the richest and the most magnificent sovereigns of his times. Our great grandchildren perhaps will despise the accommodations of the present Age, and their poverty may, in turn, be pitied by their successors.

It is obvious, however, that our desires do not aim so much at quantity as at diversity. Not only are there limits to the pleasure which commodities of any given class can afford, but the pleasure diminishes in a rapidly increasing ratio long before those limits are reached. Two articles of the same kind will seldom afford twice the pleasure of one, and still less will ten give five times the pleasure of two. In proportion, therefore, as any article is abundant, the number of those who are provided with it, and do not wish, or wish but little, to increase their provision, is likely to be great; and, so far as they are concerned, the additional supply loses all, or nearly all, its utility. And in proportion to its scarcity the number of those who are in want of it, and the degree in which they want it, are likely to be increased; and its utility, or, in other words, the pleasure which the possession of a given quantity of it will afford, increases proportionally.

But strong as is the desire for variety, it is weak compared with the desire for distinction: a feeling which, if we consider its universality and its constancy, that it affects all men and at all times, that it comes with us from the cradle, and never leaves us till we go into the grave, may be pronounced to be the most powerful of human passions.

The most obvious source of distinction is the possession of superior wealth. It is the one which excites most the admiration of the bulk of mankind, and the only one which they feel capable of attaining. To seem more rich, or, to use a common expression, to keep up a better appearance, than those within their own sphere of comparison, is, with almost all men who are placed beyond the fear of actual want, the ruling principle of conduct. For this object they undergo toil which no pain or pleasure addressed to the senses would lead them to encounter; into which no slave could be lashed or bribed. But this object is attained by appearances, and, indeed, cannot be attained by any thing else. All the gold in the Pactolus, even if the Pactolus were as rich as when Midas had just washed in it, would obviously confer no distinction on the man who was unable to exhibit it. The only mode by which wealth can be exhibited is, by the apparent possession of some object of desire which is limited in supply. Mere limitation of supply, indeed, unless there be some other circumstance constituting the article in question an object of desire, or, in other words, giving it utility, is insufficient. This circumstance must be its having some quality to which some person beside the owner annexes the notion of utility. The original manuscript of every schoolboy's exercise is as limited in supply as any thing can be, but there is nothing to make it an object of desire after it has served its purpose in school. It is merely a blotted manuscript, unique certainly, but valueless. But if the original manuscript of the *Wealth of Nations* could be discovered, it would excite an interest throughout Europe. Curiosity would be eager to trace the first workings of a mind whose influence will be felt as long as civilized society endures. It might, perhaps, be purchased by some ignorant collector only for the purposes of ostentation, but it could not serve even those purposes unless recommended by some circumstance beyond mere singularity.

* Henry, *History of Great Britain*, book vi. ch. vii.

It is impossible, however, to conceive any thing more trifling or more capricious than the circumstances which may make a thing an object of desire, and therefore, in our extended use of that word, give to it utility when its supply is narrowly limited.

The substance which at present is the greatest object of desire, and of which, therefore, a given quantity will exchange for the greatest quantity of all other things, is the diamond. A bracelet belonging to the King of Persia, the stones in which do not weigh two ounces, is said to be worth a million sterling. Now, a million sterling would command the whole labour of about thirty thousand English families for a year. If that labour were employed in producing and reproducing commodities for the purposes of sale, it would probably give for ever a clear annual income equal to the labour of three thousand families, or twelve thousand individuals. It would place at the disposal of its owner all the commodities that could be produced by all the labour of all the inhabitants of a considerable town. And a few pieces of mineral, not weighing two ounces, capable of gratifying no sense but the sight, and which any eye would be tired of looking at for a minute, is invested by our caprice with a value equal to that of the commodities which would give comfortable support to thousands of human beings in an advanced state of civilization. Hardness and brightness must have been the qualities which first attracted notice to the diamond. They enabled it to please the eye and adorn the person, and thus associated with it the notion of utility. But a diamond weighing an ounce is not found once in a century; there are not five such known to exist. The possession of an object of desire so limited in supply soon became one of the most unequivocal proofs of wealth. And, as to appear rich is the ruling passion of the bulk of mankind, diamonds will probably continue the objects of eager competition while the obstacles that limit their supply are undiminished. If a Sindbad should discover a valley of diamonds, or we should succeed in manufacturing them from charcoal, they will probably be used only as ornaments for savages, playthings for children, and as affording tools and raw materials for some of the Arts; and we may send cargoes of diamonds to the coast of Guinea to be bartered for equal quantities of ivory or gum.

Value.

Value.

Our definition of wealth, as comprehending all those things, and those things only which have *value*, requires us to explain at some length the signification which we attribute to the word value; especially as the meaning of that word has been the subject of long and eager controversy. We have already stated that we use the word value in its popular acceptation, as signifying that quality in any thing which fits it to be given and received in exchange; or, in other words, to be lent or sold, hired or purchased.

So defined, value denotes a relation reciprocally existing between two objects, and the precise relation which it denotes is the quantity of the one which can be obtained in exchange for a given quantity of the other. It is impossible, therefore, to predicate value of any object, without referring, expressly or tacitly, to some other object or objects in which its value is to be estimated; or, in other words, of which a certain quantity can be obtained in exchange for a certain quantity of the object in question.

We have already observed that the substance which at present is most desired, or, in other words, possesses the highest degree of value, is the diamond. By this we meant to express that there is no substance of which a given quantity will exchange for so large a quantity of every other commodity. When we wished to state the value of the King of Persia's bracelet, we stated first the amount of gold, and afterwards of English labour, which it would command in exchange. If we had attempted to give a perfect account of its value, we could have done so only by enumerating separately the quantity of every other article of wealth which could be obtained in exchange for it. Such an enumeration, if it could have been given, would have been a most instructive commercial lesson, for it would have shown not only the value of the diamond in all other commodities, but the reciprocal value of all other commodities in one another. If we had ascertained that a diamond weighing an ounce would exchange for one million five hundred thousand tons of Hepburn coal, or one hundred thousand tons of Essex wheat, or two thousand five hundred tons of English foolscap paper, we might have inferred that the coal, wheat, and paper would mutually exchange in the same proportions in which they were exchangeable for the diamond, and that a given weight of paper would purchase six hundred times as much coal, and forty times as much wheat.

The causes which determine the reciprocal values of commodities, or, in other words, which determine that a given quantity of one shall exchange for a given quantity of another, must be divided into two sets; those which occasion the one to be limited in supply and useful, (using that word to express the power of occasioning pleasure and preventing pain,) and those which occasion those attributes to belong to the other. In ordinary language, the *force* of the causes which give utility to a commodity is generally indicated by the word *demand*; and the *weakness* of the obstacles which limit the quantity of a commodity by the word *supply*.

Thus the common statement that commodities exchange in proportion to the demand and supply of each, means that they exchange in proportion to the force or weakness of the causes which give utility to them respectively, and to the weakness or force of the obstacles by which they are respectively limited in supply.

Unfortunately, however, the words demand and supply have not been always so used. Demand is sometimes used as synonymous with consumption, as when an increased production is said to generate an increased demand; sometimes it is used to express not only the desire to obtain a commodity, but the power to give the holder of it something which will induce him to part with it. "A demand," says Mr. Mill, *Political Economy*, p. 23, 3d edition, "means the will to purchase and the power of purchasing." Mr. Malthus, *Definitions in Political Economy*, p. 244, states that "demand for commodities has two distinct meanings: one in regard to its extent, or the quantity of commodities purchased; the other in regard to its intensity, or the sacrifice which the demanders are able and willing to make in order to satisfy their wants."

Neither of these expressions appears to be consistent with common usage. It must be admitted that the word demand is used in its ordinary sense when we say that a deficient wheat harvest increases the demand for oats and barley. But this proposition is not true if we use the word demand in any other sense than as

expressing the increased utility of oats and barley; or, in other words, the increased desire of the community to obtain them. The deficiency of wheat would not give to the consumers of oats and barley any increased power of purchasing them, nor would the quantity purchased or consumed be increased. The mode of consumption would be altered; instead of being applied to the feeding of horses, or to the supply of stimulant liquids, a certain portion of them would be used as human food. And, as the desire to eat is more urgent than the desire to feed horses, or drink beer or spirits, the desire to obtain oats and barley, or, in other words, the pleasure given, or the pain averted, by the possession of a given quantity of them, or, in other words, the *utility* of a given quantity of them, would increase. A fact which, in ordinary language, would be expressed by saying, that the demand for them was increased.

But though the vagueness with which the word demand has been used renders it an objectionable term, it is too useful and concise to be given up; but we shall endeavour never to use it in any other signification than as expressing the utility of a commodity; or, what is the same, for we have seen that all utility is relative, the degree in which its possession is desired.

We cannot complain of equal vagueness in the use of the word supply. In ordinary language, as well as in the writings of Political Economists, it is used to signify the quantity of a commodity actually brought to market. The complaint is, not that the word supply has been used in this sense, but that, when used in this sense, it has been considered as a cause of value, except in a few cases, or for very short periods. We have shown, in the examples of coats and waistcoats, and gold and silver, that the reciprocal value of any two commodities depends, not on the quantity of each brought to market, but on the comparative force of the obstacles which in each case oppose any increase in that quantity. When, therefore, we represent increase or diminution of supply as affecting value, we must be understood to mean not a mere positive increase or diminution, but an increase or diminution occasioned by a diminution or increase of the obstacles by which the supply is limited.

To revert to our original proposition, the reciprocal values of any two commodities must be determined by two sets of causes; those which determine the demand and supply of the one, and those which determine the demand and supply of the other. The causes which give utility to a commodity and limit it in supply may be called the *intrinsic* causes of its value; those which limit the supply and occasion the utility of the commodities for which it is to be exchanged, may be called the *extrinsic* causes of its value. Gold and silver are now exchanged for one another in Europe in the proportion of one ounce of gold for about sixteen ounces of silver. This proportion must arise partly from the causes which give utility to gold and limit its supply, and partly from those which create the utility and limit the supply of silver. When talking of the value of gold we may consider the first set of causes as influencing its general value, since they affect its powers of commanding every commodity in exchange. The second set of causes affect gold only so far as it is to be exchanged for silver, which may be called one of its specific values; the aggregate of its specific values forming its general value. If while the causes which give utility to silver and limit it in supply were unaltered, those which affect gold should vary; if, for instance, fashion should require every well-dressed man to have all his buttons of pure gold, or the disturbances in South America should permanently stop all the gold works of Brazil and Colombia, and thus (as would be the case) intercept five-sixths of our supplies of gold, the reciprocal values of gold and silver would in time be materially varied. Though silver would be unaltered both as to its utility and as to its limitation in supply, a given quantity of it would exchange for a less quantity of gold, in the proportion perhaps of twenty to one, instead of sixteen to one. As between one another the rise and fall of gold and silver would precisely correspond, silver would fall and gold would rise one-fourth. But the fall of silver would not be general but specific; though fallen as estimated in gold, it would command precisely the same quantities as before of all other commodities. The rise of gold would be general; a given quantity of it would command one-fourth more not only of silver, but of all other commodities. The holder of a given quantity of silver would be just as rich as before for all purposes except the purchase of gold; the holder of a given quantity of gold would be richer than before for all purposes.

The circumstances by which each different class of commodities is invested with utility and limited in supply are subject to perpetual variation. Sometimes one of the causes alone varies. Sometimes they both vary in the same direction; sometimes in opposite directions. In the last case the opposite variations, wholly or partially, neutralize one another.

The effects of an increased demand concurrent with increased obstacles to supply, and of diminished demand concurrent with increased facility of supply, are well exemplified by hemp. Its average price before the revolutionary war, exclusive of duty, did not exceed £30 per ton. The increased demand occasioned by a maritime war, and the natural obstacles to a proportionate increase of supply, raised it, in the year 1796, to above £50 a ton; at about which price it continued during the next twelve years. But in 1808, the rupture between England and the Baltic powers, the principal source of our supplies, suddenly raised it to £118 a ton, being nearly four times the average price in peace. At the close of the war, both the extraordinary demand and the extraordinary obstacles to the supply ceased together, and the price fell to about its former average.

We have already stated that the utility of a commodity, in our extended sense of the term utility, or, in other words, the demand for it as an object of purchase or hire, is principally dependent on the obstacles which limit its supply. But there are many cases in which, while the existing obstacles remain unaltered, the demand is affected by the slightest suspicion that their force may at a future period be increased or diminished. This occurs with respect to those commodities of which the supply is not susceptible of accurate regulation, but is afforded either in uncertain quantities and at stated periods, between which it cannot be increased or diminished,—in the case for instance of the annual products of the earth,—or is dependent on our relations with foreign Countries. If a harvest deficient by one-third should occur, that deficiency must last for a whole year, or be supplied from abroad at an extravagant cost. If we should go to war with Russia, the obstacles to the supply of hemp would be increased while the war lasted. In either case the holders of corn or hemp would obtain great profits. In all rich Countries, and particularly in our own, there is a great number of persons who have

large masses of wealth capable of being suddenly applied to the purchase of any given objects. The instant such persons suspect that the obstacles to the supply of any article are likely to be increased, they are anxious to become holders of it. They enter the market as new demanders; the price rises, and the mere fact that it has risen is a cause of its rising further. The details of commerce are so numerous, the difficulty of obtaining early and accurate information is so great, and the facts themselves are so constantly changing, that the most cautious merchants are often forced to act upon very doubtful premises; and the imprudent, dazzled by the chance of an enormous gain, which will be their own, and little restrained by the fear of a loss which may principally fall upon their creditors, are often ready to act upon scarcely any premises at all. They see that the price of some article has risen, and they suppose that there must be some good cause for it. They see that if they had purchased a month ago, they would have been gainers now, and conclude that if they purchase now they will be gainers a month hence. So far is this reasoning, if it can be called reasoning, carried, that a rise in the price of any one important commodity is generally found to occasion a rise in the price of many others. "A" (thinks a speculator) "bought hemp before the price had risen and has resold it at a profit. Cotton has not yet risen, nor do I see clearly why it should rise, any more than I see why hemp should have risen, but it probably will rise like hemp, therefore I will purchase."

Those who are not practically conversant with commercial transactions, and who are probably accustomed to consider our merchants and capitalists as men of sober minds, and cautious conduct, may perhaps think that we exaggerate the influence of imagination over judgment when we suppose that large fortunes are often risked on such reasoning as this. We cannot support our view better than by the authority of Mr. Tooke, a merchant of great talent and knowledge, and, at the period when he wrote, forced, for his own safety, to watch narrowly the phenomena which he described. The passages which we subjoin are taken from his account of the circumstances which occasioned the extraordinary rise of prices in the beginning of 1825. "The close of each year* is the period at which, by annual custom, the stocks of goods on hand, and the prospects of supply and consumption for the coming season, are stated and reasoned upon by merchants and brokers in circular letters addressed to their correspondents and employers. By these circulars it appeared (at the close of 1824) that, of some important articles, the stock on hand fell short of that at the close of the preceding year. From this the conclusion was more or less plausibly deduced, that the rate of the annual consumption of those articles was outrunning the rate of the annual supply, and that an advance in price ought to take place; and at the same time, there were, as in the case of cotton and silk, confident reports of the failure of crops or other causes which would inevitably diminish the forthcoming supply. Expectation of scarcity was thus combined with actual deficiency in exciting the spirit of speculation. This was directed in the first instance to the articles which, upon fair mercantile grounds, justified and called for some advance in price, inasmuch as the rate of the consumption of them had outrun the average rate of supply. The rise, however, which would have been requisite to increase the supply, or to diminish the consumption, would, in most of the cases in question, have been trifling.

"But when speculation is once on foot, the rise of any one article may not only be in a ratio far greater than the occasion really calls for, but may cause indirectly a rise in other commodities.

"The impulse, therefore, to a rise being given, and every succeeding purchaser having realized, or appearing to have the power of realizing, a profit, a fresh inducement appeared in every step of the advance to bring forward new buyers. These were no longer such only as were conversant with the market: many persons were induced to go out of their own line, and to embark their funds, or stretch their credit, with a view to engage in what was represented to them by the brokers a certain means of realizing a great and immediate gain.

"Cotton exhibited the most extraordinary instance of speculation carried beyond all reasonable bounds. Silk, wool, and some other articles in which some advance was justified by the relative state of the supply and demand, became the subjects of a speculative anticipation, and advanced much beyond the occasion, as the event proved, though not in so great a degree as cotton.

"Never did the public, that part of it at least which entered into the vortex of the operations in question, exhibit so great a degree of infatuation, so complete an abandonment of all the most ordinary rules of mercantile reasoning since the celebrated bubble year 1720, as it did in the latter part of 1824, and in the first three or four months of 1825.

"The speculative anticipation of an advance was no longer confined to articles which presented a plausible ground for some rise however small. It extended itself to articles which were not only not deficient in quantity but which were actually in excess. Thus coffee, of which the stock was increased compared with the average of former years, advanced from 70 to 80 per cent. Spices rose in some instances from 100 to 200 per cent. without any reason whatever, and with a total ignorance on the part of the operators of every thing connected with the relation of the supply to the consumption.

"In short, there was hardly an article of merchandise which did not participate in the rise. For it became the business of the speculators or the brokers, who were interested in raising and keeping up prices, to look minutely through the general Price Currents with a view to discover any article which had not advanced, in order to make it the subject of anticipated demand.

"If a person not under the influence of the prevailing delusion ventured to inquire for what reason any particular article had risen, the common answer was, 'Every thing else has risen, and therefore this ought to rise.'"

When we consider that the supply of large classes of commodities is dependent on our amicable or hostile relations with foreign States, and on the commercial and financial legislation both of those States and of our own Country, and that the supply of still larger classes is dependent not only on those contingencies, but on the accidents of the seasons,—and when we consider how the demand is affected not merely by the existing, or the anticipated obstacles to the supply, but often by a spirit of speculation as blind as that of a gambler ignorant of the odds and even of the principles of his game,—it is obvious that the general value of all commodities, the

* *Considerations on the State of the Currency*, p. 43.

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Value.

quantity of each which will exchange for a given quantity of every other, can never remain the same for a single day. Every day there will be a variation in the demand or the supply of one or more of the innumerable classes of commodities which are the objects of exchange in a commercial Country. A given quantity of the commodity which has varied will consequently exchange for a greater or a less quantity of all other commodities. All other commodities, therefore, will have varied in value as estimated in the first-mentioned commodity. It is as impossible for one commodity to remain perfectly unaltered in value while any other is altered, as it would be for a light-house to keep at the same distance from all the ships in a harbour while any one of them should approach it or recede.

But it may be asked, what do we mean when we say that a commodity has, for a given period, remained *steady* in value?

The question must be answered by referring to the different effects produced on the value of a commodity by an alteration in the intrinsic, or an alteration in the extrinsic, causes on which value depends. If the causes which give utility to a commodity and limit its supply, and which we have called the intrinsic causes of its value, are altered, the rise or fall in its value will be general. A given quantity of it will exchange for a greater or a less quantity than before of every other commodity which has not also varied at the same time, in the same direction, and in the same degree; a coincidence which rarely occurs. Every other commodity must also rise or fall in value as estimated in the first-mentioned commodity, but not generally.

The fluctuations in value to which a commodity is subject by alterations, in what we have called the extrinsic causes of its value, or, in other words, by alterations in the demand or supply of other commodities, have a tendency, like all other extensive combinations of chances, to neutralize one another. While it retains the same utility, and is limited in supply by the same causes, a given quantity of it, though it may exchange for a greater or a less quantity of different specific commodities, will in general command the same average quantity as before of the general mass of commodities; what it gains or loses in one direction being made up in another. It may be said, without impropriety, therefore to remain steady in value. But the rise or fall in value which a commodity experiences in consequence of an alteration in its utility, or in the obstacles to its supply, is, in fact, entirely uncompensated. It is compensated only with regard to those commodities of which the utility or the supply has also varied at the same time and in the same direction. And as quite as many are likely to experience a similar variation, but in an opposite direction, there is really *no* compensation. A commodity, therefore, which is strikingly subject to such variations, is properly said to be unsteady in value.

But we may be asked to account for another and not unfrequent statement, that at particular periods *all* commodities have been observed to rise or fall in value. Literally taken, this statement involves a contradiction in terms, since it is impossible that a given quantity of every commodity should exchange for a greater or a less quantity of every other. When those who make this statement have any meaning, they always tacitly exclude some one commodity, and estimate in that the rise or fall of all others. The excluded commodity is, in general, money or labour.

Estimated in labour, all commodities, money included, have fallen in value in England since the XVIth Century. It is scarcely possible to mention one of which a given quantity will not purchase less labour than it did at the close of Elizabeth's reign; estimated in money, almost all commodities, labour included, have fallen in England since the termination of the late war.

The last remark which we shall now make on value is, that, with a very few exceptions, it is strictly local. A ton of coal at the bottom of the pit near Newcastle is perhaps worth 2*s.* 6*d.*, at the pit's mouth it is perhaps worth 5*s.*, at ten miles off 7*s.*, at Hull 10*s.* By the time the collier has reached the Pool, its cargo is seldom worth less than 16*s.* a ton; and the inhabitant of Grosvenor Square may perhaps think himself fortunate if he can fill his coal cellars at 25*s.* a ton.* A ton of coal, though physically identical, must be considered, for economical purposes, as a different commodity at the bottom of the pit and at its mouth, in Hull and in Grosvenor Square. At every different stage of its progress it is limited in supply by different obstacles, and consequently exchangeable for different things and in different proportions. Supposing that at Newcastle a ton of the best wheat is now worth about twenty tons of the best coal: the same wheat and coal at the west end of London may probably exchange in the proportions of about four tons of coal for one of wheat. At Odessa, they may perhaps exchange about weight for weight.

Whenever, therefore, we speak of the value of a commodity, it is necessary to state the locality both of the commodity in question, and of the commodity in which its value is estimated. And in most cases we shall find their respective proximity to the places where they are respectively to be made use of one of the principal constituents of their respective values. The purchaser of the distant commodity has to consider the labour of transporting it to the place of consumption, the time for which that labour must be paid in advance, and the taxation, and the risk of injury or loss to which it may be subject in its transit. Nor is this all. He must also consider the danger that its quality may not correspond with the description or sample which guided him in making the purchase. The whole expense and risk attending the transport of a diamond from Edinburgh to London are but trifling; but its value is so dependent on its form and lustre, and those are qualities as to which it is so difficult to satisfy any purchaser who cannot ascertain them by inspection, that it would be difficult to obtain in London a fair price for a diamond in Edinburgh. Again, though a given quantity of coal from a given mine is generally of an ascertained quality, yet the expense, loss of time, risk, and taxation, which must be incurred in its transport from Newcastle to Grosvenor Square, are such that a ton of coal, when it has reached Grosvenor Square, may be of nearly five times the value which it bore at Newcastle.

Objections to Definition of Wealth considered.

Objections to definition of wealth considered.

The definition of wealth, as comprehending all those things, and those things only, which have value, or, in other words, which may be purchased or hired, does not, we believe, precisely agree with that adopted by any Economist except Archbishop Whately.

* These prices are merely assumed for the purpose of illustration.

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Objections to definition of wealth considered.

The principal differences are these: some writers confine the term wealth to what have been termed material products; some to those things which have been produced or acquired by human labour; and some object to the ideas of value or exchange being introduced into the definition of wealth.

The question whether the things which have been called immaterial ought to be considered articles of wealth, we shall consider when we treat of production.

Some of the writers who, expressly or impliedly, restrict the term wealth to the things, the production or appropriation of which has cost human labour, as for instance Mr. Mill, Mr. M'Culloch, Colonel Torrens, Mr. Malthus, and M. Flores-Estrada, appear to suppose that a definition so restricted will comprise every thing that can properly be termed wealth; others, among whom is Mr. Ricardo, admit that there are some things falling within that term which have not been acquired by human exertion, but think them so few or unimportant that it is better to omit them than to disorder the symmetry of the Science by extending it to any thing that is not the result of labour.

The former doctrine is clearly stated in the following passages from Mr. Malthus, Colonel Torrens, and Mr. M'Culloch.

"Wealth. The material things necessary, useful, or agreeable to man, which have required some portion of human exertion to appropriate or produce."*

"Wealth, considered as the object of economical Science, consists of those material articles which are useful or desirable to man, and which it requires some portion of voluntary exertion to procure or to preserve. Thus two things are essential to wealth: the possession of utility, and the requiring some portion of voluntary exertion or labour. That which has no utility, which serves neither to supply our wants, nor to gratify our desires, is as the dust beneath our feet, or as the sand upon the shore, and obviously forms no portion of our wealth; while, on the other hand, things which possess the highest utility, and which are even necessary to our existence, come not under the denomination of wealth, unless to the possession of utility be superadded the circumstance of having been procured by some voluntary exertion. Though the air which we breathe and the sunbeams by which we are warmed are in the highest degree useful and necessary, it would be a departure from the precision of language to denominate them articles of wealth. But the bread which appeases the cravings of hunger, and the clothing which protects us from the rigour of the season, though not more indispensably requisite than the former, are with propriety classed under the term wealth; because to the possession of utility they add the circumstance of having been produced by labour."†

"Labour is the only source of wealth. Nature spontaneously furnishes the matter of which all commodities are made; but until labour has been expended in appropriating matter, or in adapting it to our use, it is wholly destitute of value, and is not, nor ever has been, considered as forming wealth. Place us on the banks of a river, or in an orchard, and we shall inevitably perish of thirst or hunger, if we do not, *by an effort of industry*, raise the water to our lips, or pluck the fruit from its parent tree.

* Malthus, *Definitions*, p. 234.

† Torrens, *Production of Wealth*, ch. i.

"An object which it does not require any portion of labour to appropriate or to adapt to our own use may be of the very highest utility, but, as it is the free gift of nature, it is utterly impossible it can possess the smallest value."*

Mr. M'Culloch appears to use the word labour as including all voluntary action. And without doubt, if we use the word labour in so extended a sense, it is true that labour is almost necessarily incidental to the *enjoyment* of wealth. If it be an act of industry to gather an apple, it is equally an act of industry to raise it from one's plate; and every guest at a festival earns his food by the labour which he exerts in appropriating his own portion. Such attempts as these to bend facts and language into accordance with hasty generalization have thrown on Political Economy a degree of ridicule which is one of the principal obstacles to its progress.

Mr. Malthus, Colonel Torrens, and the other Economists who consider labour, using that word in its popular sense, as a necessary constituent of wealth, appear to have been led to that opinion by observing, first, that some quality besides mere utility is necessary to value; secondly, that all those things which are useful, and are acquired by labour, are valuable; and thirdly, that almost every thing which is valuable *has* required some labour for its acquisition. But the fact that that circumstance is not essential to value will be demonstrated if we can suppose a case in which value could exist without it. If, while carelessly lounging along the sea-shore, I were to pick up a pearl, would it have no value? Mr. M'Culloch would answer that the value of the pearl was the result of my appropriative industry in stooping to pick it up. Suppose then that I met with it while eating an oyster? Supposing that aerolithes consisted of gold, would they have no value? Or, suppose that meteoric iron were the only form in which that metal were produced, would not the iron supplied from heaven be far more valuable than any existing metal? It is true that, wherever there is utility, the addition of labour as necessary to production constitutes value, because, the supply of labour being limited, it follows that the object, to the supply of which it is necessary, is by that very necessity limited in supply. But any other cause limiting supply is just as efficient a cause of value in an article as the necessity of labour to its production. And, in fact, if all the commodities used by man were supplied by nature without any intervention whatever of human labour, but were supplied in precisely the same quantities as they now are, there is no reason to suppose either that they would cease to be valuable, or would exchange in any other than their present proportions.

The reply to Mr. Ricardo is, first, that the articles of wealth which do not owe the principal part of their value to the labour which has been bestowed on their respective actual production, form, in fact, the bulk of wealth instead of a small and unimportant portion of it; and secondly, that, as limitation of supply is essential to the value of labour itself, to assume labour, and exclude limitation of supply, as the condition on which value depends, is not only to substitute a partial for a general cause, but pointedly to exclude the very cause which gives force to the cause assigned.

We have lastly to consider the objections which have been raised to the definition of wealth as a general name for the things which have value. Those who use the

* *Principles of Political Economy*, 66—72.

Political Economy.

Objections to definition of wealth considered.

word value as synonymous with *cost*, or as comprehending whatever is useful, of course object to its introduction into the definition of wealth; and so should we do if we used the word value in either of those senses. But other writers, using the word value in its popular sense, have objected that, according to the definition which we have adopted, the same thing will be wealth to one person and not to another. This consequence is evident; and it is evident that even to the same person the same quality may be wealth under some circumstances, and not so under others. The knowledge of English law is profitable in England, that of French law in France; if an English lawyer, with no other property than his knowledge, were to settle in France, or a French lawyer in England, he would find himself instantly reduced from affluence to poverty. The power of telling long stories is a source of profit in Asia, but valueless in Europe. According to our nomenclature, therefore, it would be wealth in Persia, and cease to be so in England. If an actress should embrace a religious sect of which the tenets should be incompatible with the stage, her vocal and dramatic talents would no longer be exchangeable, she would no longer be able to let them out by the evening. We should say, therefore, that they had ceased to be a part of her wealth. But we are at a loss to conceive how the power of making this distinction is an objection to the language in question. It seems to be its principal convenience.

Again, Colonel Torrens supposes a solitary family, or a nation in which each person should consume only his own productions, or one in which there should be a community of goods, and urges, as a *reductio ad absurdum*, that in these cases, though there might be an abundance of commodities, as there would be no exchanges, there would, in our sense of the term, be no wealth. The answer is, that, for the purposes of Political Economy, there would be no wealth; for, in fact, in such a state of things, supposing it possible, the Science of Political Economy would have no application. In such a state of society, Agriculture, Mechanics, or any other of the Arts which are subservient to the production of the commodities which are, with us, the subjects of exchange, might be studied, but the Science of Political Economy would not exist. We may add, that if the common usage which identifies wealth with the things which have value is a convenient one in all the forms which human nature really exhibits, it is no objection to it that it would not be convenient in a state of society of which we have no experience.

Statement of the four Elementary Propositions of the Science.

Statement of the elementary propositions of the Science.

We have already stated that the general facts on which the Science of Political Economy rests are comprised in a few general propositions, the result of observation or consciousness. The propositions to which we then alluded are these:

1. *That every man desires to obtain additional wealth with as little sacrifice as possible.*

2. *That the population of the world, or, in other words, the number of persons inhabiting it, is limited only by moral or physical evil, or by fear of a deficiency of those articles of wealth which the habits of the individuals of each class of its inhabitants lead them to require.*

3. *That the powers of labour, and of the other instruments which produce wealth, may be indefinitely increased by using their products as the means of further production.*

4. *That, agricultural skill remaining the same, additional labour employed on the land within a given district produces in general a less proportionate return, or, in other words, that though, with every increase of the labour bestowed, the aggregate return is increased, the increase of the return is not in proportion to the increase of the labour.*

The first of these propositions is a matter of consciousness, the three others are matter of observation. As the first and second involve little use of the peculiar abstractions of Political Economy, except those implied in the term wealth, and may therefore be explained with little recourse to its peculiar nomenclature, we shall consider them immediately; leaving the third and fourth for discussion in a subsequent part of this Treatise. They are however so nearly self-evident, that we will venture in the mean time to assume their truth. No one who reflects on the difference between the unassisted force of man, and the more than gigantic powers of capital and machinery, can doubt the former proposition; and, to convince ourselves of the other, it is necessary only to recollect that, if it were false, no land except the very best could ever be cultivated: since, if the return from a single farm were to increase in full proportion to any amount of increased labour bestowed on it, the produce of that one farm might feed the whole population of England.

General Desire for Wealth.

General desire for wealth.

In stating that every man desires to obtain additional wealth with as little sacrifice as possible, we must not be supposed to mean, that every body, or indeed any body, wishes for an indefinite quantity of every thing; still less as stating that wealth, though the universal, either is, or ought to be, the principal object of human desire. What we mean to state is, that no person feels his whole wants to be adequately supplied; that every person has some unsatisfied desires which he believes that additional wealth would gratify. The nature and the urgency of each individual's wants are as various as the differences in individual character. Some may wish for power, others for distinction, and others for leisure; some require bodily, and others mental amusement; some are anxious to produce important advantage to the public; and there are few, perhaps there are none, who, if it could be done by a wish, would not benefit their acquaintances and friends. Money seems to be the only object for which the desire is universal; and it is so, because money is abstract wealth. Its possessor may satisfy at will his ambition, or vanity, or indolence, his public spirit or his private benevolence; may multiply the means of obtaining bodily pleasure, or of avoiding bodily evil, or the still more expensive amusements of the mind. Any one of these pursuits would exhaust the largest fortune within the limits of individual acquisition; and, as all men would engage in some of them, and many in all, the desire for wealth must be insatiable, though the modes in which different individuals would employ it are infinitely diversified.

An equal diversity exists in the amount and the kind of the sacrifices which different individuals, or even the same individual, will encounter in the pursuit of wealth.

Political Economy.

General desire for wealth.

And not only is the same sacrifice more severe to one than to another, as some will not give up ease or leisure for study, others good air and a country life, and others recreation and society, but the absolute desire for wealth on the one hand, and the absolute will to encounter toils or privations in its pursuit on the other, are stronger in some men than in others. These differences form some of the principal distinctions in individual and national character. Experience, however, shows, and indeed it might have been predicted *à priori*, that the greatest and longest continued sacrifices will be made in those Countries in which property is most secure, and the road to social eminence is the most open. The inhabitants of Holland and of Great Britain, and of the Countries that have derived their institutions from Great Britain, the nations which up to the present time have best enjoyed those advantages, have up to the present time been the most ardent and the most successful in the pursuit of opulence. But even the Indians of Mexico, though their indolence makes them submit to poverty under which an Englishman would feel life a burthen, would willingly be rich if it cost them no trouble.

It may be necessary, however, to explain our motives for dwelling on so much that is self-evident. Our first reason is, that the proposition in question, though we are not aware that any one has thought that it required to be formally stated, is assumed in almost every process of economical reasoning. It is the corner-stone of the doctrine of wages and profits, and, generally speaking, of exchange. In short, it is in Political Economy what gravitation is in Physics, or the *dictum de omni et nullo* in Logic: the ultimate fact beyond which reasoning cannot go, and of which almost every other proposition is merely an illustration. In an attempt to state the evidence on which the Science rests, it appeared to us improper to omit its foundation, though at the hazard of appearing to take up our reader's time in defending what it may be supposed that nobody ever thought of questioning.

But, in the second place, this proposition, apparently self-evident, *has* been impliedly questioned. It is directly opposed to a doctrine of considerable popularity, and supported by great names,—we mean the doctrine of over-production or *universal* glut.

By the word glut is meant the production of a given commodity in an abundance, either absolutely beyond the desires of its intended consumers, or beyond the amount for which they are able and willing to offer in exchange equivalents sufficient to induce the producer to continue his operations. Books are, perhaps, the commodities most subject to gluts. The proportionate expenses of printing and advertising increase so rapidly, if the number of copies printed be much reduced, and authors are so little subject to underrate the probable demand for their labours, that scarcely any edition consists of less than two hundred and fifty copies, and very few of less than five hundred. But we have seen calculations showing that not in one case out of two hundred are all the copies sold off at the price at which they originally came out. In ordinary cases, from fifty to one hundred are sold in the first year, and thirty or forty in the second; by the end of which time the book has been forgotten, and the unsold copies are put up to sale at periodical auctions among the booksellers. The best that can happen to them is to be purchased on this occasion in order to be again offered to the public; but the majority of Works are found to be worth purchase not as books, but as paper. They are unsold at the trade sales, and find their way

> *In vicum vendentem thus et odores*
> *Et piper, et quidquid chartis amicitur ineptis.*

We have selected books as affording an illustration of a glut arising from a miscalculation not of the ability, but of the willingness of purchasers. The opening of a new trade is generally followed by gluts occasioned by miscalculations of both. Every one must recollect, when Brazil and Spanish America first became accessible, our exports of skaits, and fire-irons, and warming pans to the tropics. And, until their real poverty was known, we continued to fill their warehouses with cargoes, adapted indeed to their wants, but far beyond their means. Miscalculations of this kind must obviously be of frequent occurrence; and perhaps what ought to excite our surprise is, not the extent to which they prevail, but the degree in which they are avoided. But it appears clear that they can arise only from one or the other of two causes: either from the articles of wealth, with respect to which the glut exists, having been prepared for persons who do not want them, or from those persons not being provided with other articles of wealth, suited to the desires of the producers of the first-mentioned articles of wealth, to offer in exchange for them. Partial gluts, occasioned by the one or the other of these causes, are among the most ordinary commercial occurrences. But the opinion to which our doctrine is opposed is that which admits the possibility not only of partial but of *universal* gluts, which supposes it possible that there may be at the same time a glut of services and commodities in general, —that we may have too much of every thing; a doctrine not only of frequent occurrence in conversations on commercial subjects, but even maintained by some distinguished writers. Now as by the assumed hypothesis of a universal glut all the articles of wealth exist not only in abundance, but in superabundance, an absolute deficiency of equivalents cannot be one of its causes. And it can scarcely be supposed that there can be such a general state of commercial cross-purposes as to prevent, in the majority of cases, the proper sellers and purchasers from meeting. It can scarcely be supposed that when A has what B wants, and B what A wants, A and B should, in the majority of instances, instead of finding out and exchanging with one another, offer their respective commodities to Y and Z, who, having also each reciprocal wants and supplies, neither wish to purchase from A or B, nor have discovered the means of exchanging with one another. But if it be absurd to suppose that a general glut could be occasioned by such an universal spirit of blundering as this, the only remaining hypothesis on which the existence of a general glut can be supposed is that of a general satiety, that all men may be so fully provided with the precise articles which they desire as to afford no market for each other's superfluities. And this doctrine is opposed to the proposition with which we set out, that every man desires to obtain additional wealth.

Population.

Population.

Having explained the sense in which we use the word wealth, and stated, or rather recalled to the recollection of our readers, the general desire to obtain additional wealth with the least possible sacrifice, we now proceed

to consider the second of the four elementary propositions on which the Science of Political Economy is founded; namely, that the population of the world, or, in other words, the number of persons inhabiting it, is limited only by moral or physical evil, or by fear of the deficiency of those articles of wealth which the habits of the individuals of each class of its inhabitants lead them to require.

It is now generally admitted, indeed it is strange that it should ever have required to be pointed out, that every species of plant or animal which is capable of increase, either by generation or by seed, must be capable of a constantly increasing increase; every addition to its numbers being capable of affording a source of still further additions; or, in other words, that wherever there is a capacity of increase, it must be a capacity of increase not by mere addition but by multiplication; or, to use the short form in which the proposition is usually stated, not in an arithmetical, but in a geometrical ratio. The rate at which any species of plant or animal is capable of increasing must depend on the average power of reproduction and the average period of existence of the individuals of which it is constituted. Wheat, we know, is an annual, and its average power of reproduction, perhaps, about six for one; on that supposition, the produce of a single acre might cover the globe in fourteen years. The rate at which the human race is capable of increasing has been determined by observation. It has been ascertained that, for considerable periods and in extensive districts, under temperate climates, it has doubled every twenty-five years.

The power of reproduction in the human race must, under similar climates, be always the same. We say, under similar climates, because the acceleration of puberty, which has been sometimes observed in tropical climates, unless checked, as is probably the case by an earlier cessation of child-bearing, would occasion increased fecundity. Now, the United States of America, the districts in which the rate of increase which we have mentioned has been most clearly ascertained, are not remarkable for the longevity of their inhabitants. We may infer, therefore, that such is the average power of reproduction and average duration of life in the individuals constituting the human species, that their number may double every twenty-five years. At this rate the inhabitants of every Country would, in the course of every five centuries, increase to above a million times their previous number. At this rate the population of England would, in five hundred years, exceed fifteen million millions: a population which would not allow them standing room. Such being the human powers of increase, the question is, by what checks is their expansion controlled? How comes it that the population of the world, instead of being now a million times as great as it was five hundred years ago, apparently has not doubled within that time, and certainly has not quadrupled?

Mr. Malthus has divided the checks to population into the preventive and the positive. The first are those which limit fecundity, the second those which decrease longevity. The first diminish the number of births, the second increase that of deaths. And as fecundity and longevity are the only elements of the calculation, it is clear that Mr. Malthus's division is exhaustive. The positive check to population is physical evil. The preventive checks are promiscuous intercourse and abstinence from marriage. The first is moral evil; the second is, with a very few exceptions, so few indeed that they do not affect the result, founded on an apprehended deficiency of some of the things to which we have given the general appellation of wealth. All the preventive and positive checks may therefore be distributed under prudence, moral evil, and physical evil. We will first consider the positive check.

We have seen that this check includes all the causes which tend, in any way, prematurely to shorten the duration of human existence: such as unwholesome occupations, severe labour, or exposure to the seasons, bad or insufficient food or clothing, bad nursing of children, excesses of all kinds, the corruption of the air from natural causes, or from large towns, wars, infanticide, plague, and famine. Of these, some arise from the laws of nature, and others from the crimes and follies of man: all are directly and immediately felt in the form of physical evil, though many of them are the result, more or less remotely, of moral evil.

The final and irresistible mode in which physical evil operates is the want of the necessaries of existence: death produced by hardship or starvation. This is almost the only check to the increase of the irrational animals, and as man descends towards their condition he falls more and more under its influence. In the lowest savage state it is the principal and obvious check; in a high state of civilization it is almost imperceptible; but is unperceived only in consequence of the operation of its substitutes.

We have already stated that, as a general rule, additional labour employed in the cultivation of the land within a given district produces a less proportionate return. And it has appeared that such is the power of reproduction and duration of life in mankind, that the population of a given district is capable of doubling itself at least every twenty-five years. It is clear, therefore, that the rate at which the production of food is capable of being increased, and that at which population, if unchecked, would increase, are totally different. Every addition made to the quantity of food periodically produced makes in general a further periodical addition more difficult. Every addition to the existing population diffuses wider the means of still further addition. If neither evil, nor the fear of evil, checked the population of England, it would amount in a century to above two hundred millions. Suppose it possible that we might be able to raise or to import the subsistence of two hundred millions of people: is it possible that one hundred and twenty-five years hence we should be able to support four hundred millions? or, in one hundred and fifty years, eight hundred millions? It is clear, however, that long before the first century had elapsed, long before the period at which, if unchecked, we should have attained two hundred millions, no excellence in our institutions, or salubrity of climate, or unremitting industry, could have saved us from being arrested in our progress by a constantly increasing want of subsistence. If all other moral and physical checks could be got rid of, if we had neither wars nor libertinism, if our habitations, and employments, and habits were all wholesome, and no fears of indigence or loss of station prevented or retarded our marriages, famine would soon exercise her prerogative of controlling, in the last resort, the multiplication of mankind.

But though it be certain that the absence of all other checks would only give room for the irresistible influence of famine, it is equally certain that such a state of things never has existed and never will exist.

In the first place the absence of all the other moral and physical evils which retard population implies a degree of civilization not only high, but higher than mankind have as yet enjoyed. Such a society cannot be supposed to want sagacity sufficient to foresee the evils of a too rapidly increasing population, and prudence sufficient to avoid them. In such a state the preventive check would be in full operation, and its force is quite sufficient to render unnecessary even the approach of any positive check.

And, secondly, it is impossible that a positive check, so goading and so remorseless as famine, should prevail without bringing in her train all the others. Pestilence is her uniform companion, and murder and war are her followers. Whole bodies of men will not tamely lie down to die, and witness, while they are perishing, their wives, and children, and parents, starving around them. Where there is a diversity of fortunes, famine generally produces that worst form of civil war, the insurrection of the poor against the rich. Among uncivilized nations it produces those tremendous hostile migrations in which a whole people throws itself across a neighbouring frontier, and either perishes in the attempt to obtain a larger or a more fertile territory, or destroys the former possessors, or drives them out to be themselves aggressors in turn.

In fact, almost all the positive checks, by their mutual reaction, have a tendency to create and aggravate one another; and the destruction of those who perish immediately by one may generally be found to have been remotely occasioned or promoted by one or more of the others. Among nations imperfectly civilized the widest and the most wasting of the positive checks is predatory war. A district exposed to it is likely to suffer all the others. Mere fear of invasion must generally keep the great body of its inhabitants pent up in crowded and consequently unwholesome towns; it must confine their cultivation to the fields in the immediate neighbourhood of those towns, and, if it does not destroy, must so much impede their commerce as to render it useless as a source of subsistence; and when the invasion does come, it is often followed by the complete extirpation of the invaded community. This is the check which has kept Africa, and the central parts of Asia, in their comparatively unpeopled state.

In his journey from Abyssinia to Sennaar, Bruce crossed the territory of Atbara, subject to the incursions of the Daveina Arabs. The whole seems to have been a scene of desolation. He passed a night at Garigara, a village, of which they had destroyed the crops a year before. The inhabitants had all perished with hunger, and their remains were unburied and scattered over the ground where the village had stood. The travellers encamped among the bones: no space could be found free from them. His next stage was Teawa. "Its consequence," he observes, "was to remain only till the Daveina should resolve to attack it, when its corn fields being burnt and destroyed in a night by a multitude of horsemen, the bones of its inhabitants scattered upon the earth would be all its remains, like those of the miserable village of Garigara."

Among the positive checks to the population of uncivilized, or partially civilized, nations, the next in importance to war is famine. When a people depends principally on that subsistence which is most easily obtained, and such is the case among the nations in question, the mere variations of the seasons must, from time to time, produce destructive want. Where society is better constituted, the evil of these variations is mitigated, partly from the superfluity of the more opulent classes, partly by importation, and principally by a recurrence to a less expensive diet; but in a barbarous, and consequently a poor and non-commercial people, they are among the most frighful forms of national calamity. The histories which we possess of such Countries always particularize periods of dearth as among the most memorable events recorded. They seem in a constant oscillation between the want endured by a population that has increased to the utmost limits of subsistence, and the plenty enjoyed by the survivors after that population has been thinned by war, pestilence, or famine. The remainder of the positive checks, such as infanticide and unwholesomeness of climate, habits, or situation, appear rather to facilitate early marriages than to produce any actual diminution, or prevent any actual increase of population. Infanticide has been supposed to be rather favourable to population, by opposing to the prudential check to marriage a mode of disposing of its offspring, which may appear easy in contemplation, but from which the feelings of the parents eventually recoil. The unwholesomeness of some districts is unquestionably such as to keep them totally unpeopled, or inhabited by strangers, whose numbers must be constantly recruited. Such, for instance, appears to be the case in the most unhealthy parts of Italy. Such is the case with large manufacturing towns even in the most favourable climates, unless great skill and great care are directed towards their cleanliness and ventilation. And in a newly colonized Country like the back settlements of America, where the abundance of land and the constantly increasing means of subsistence would render any preventive check unnecessary, any cause diminishing longevity must retard increase. But with these exceptions, unhealthiness rather causes the successive generations to pass more rapidly away, than diminishes the actual number of inhabitants. In some of the healthiest districts of Swisserland the average annual mortality does not exceed one in forty-eight. In many of the marshy villages of Holland it exceeds one in twenty-three. But it would be rash to expect the population of the former to be more dense or to increase more rapidly than that of the latter. The case is, in fact, the reverse. In the Swiss villages of which we have been speaking the births are as rare as the deaths; the population is thin and stationary. Among the Dutch the births somewhat exceed the deaths; the population is dense and is increasing. It is obvious, indeed, that the proportion of annual births to the whole number of people being given, the rate of increase must depend on the proportion borne by the annual deaths. And again, the proportion of deaths to the whole number of people being given, it must depend on the proportion borne by the births; or, to use a shorter form of expression, given the longevity it must depend on the fecundity, and given the fecundity it must depend on the longevity. If both are given, the rate of increase may be calculated; but from only one, the conclusion must be in the disjunctive. If the annual births bear a large proportion to the existing number of people, we may conclude either that the population is rapidly increasing, or that the positive checks are in powerful operation. On the other hand, from a small proportion of annual deaths may be inferred either a rapid increase of numbers, or a

strong influence of the preventive checks. The average duration of life in England is greater than in the United States of America; but so much greater is the force of the preventive checks, that the rate of increase in America is about double that in England. Again, the average duration of life in the Swiss villages to which we have referred is the same as it is in England; but the preventive check in England, strong as it appears when compared with its force in America, is so much weaker than it is in some districts in Swisserland, that, with the same annual mortality, the population is in the one Country stationary, in the other rapidly progressive.

But although the average longevity in a Country affords no decisive evidence as to the increasing or stationary number of its inhabitants, it is among the least deceitful tests of their prosperity; far less so than that on which legislators formerly relied, the number of births. There is not an evil, moral or physical, which has not a tendency, directly or indirectly, to shorten life, but there are many which have a direct tendency to increase fecundity. The extraordinary duration of life in Great Britain, exceeding, as it does, the average of any other equally populous district, is a convincing proof of the general excellence of our climate, our institutions, and our habits.

We now proceed to consider the preventive checks to the increase of population. We have seen that they are promiscuous intercourse and abstinence from marriage.

The first does not appear to be of sufficient importance to require much consideration. It is said to produce some effect in checking the increase of the higher classes in some of the South Sea Islands; and it appears to have produced the same effect to a considerable extent among the West Indian negroes. But the nobility of the South Seas scarcely deserve to be separately considered. And, while the other forms of moral and physical evil were accumulated, as they were among the West Indian slaves, it is probable that the removal of this evil alone would have done little to promote the increase of their population.

But, with these exceptions, there are scarcely any females whose fecundity is prevented or diminished by promiscuous intercourse, except those unhappy individuals whose only trade is prostitution. And they form so small a proportion of the population of the whole world that the check to population, occasioned by their unfruitfulness, may safely be disregarded.

The only remaining check is abstinence from marriage. Our readers are of course aware that, by the word "marriage," we mean to express not the peculiar and permanent connection which alone, in a Christian Country, is entitled to that name, but any agreement between a man and woman to cohabit under circumstances likely to occasion the birth of progeny. We have already observed that abstinence from marriage is almost uniformly founded on the apprehension of a deficiency of some of the things which we have denominated by the general term wealth, or, in other words, on prudence. Some cases certainly occur in which men remain unmarried, although their fortunes are so ample that the expenses of a family would be unperceived. But the number of persons so situated is so small that they create an exception which would scarcely deserve attention, even if this conduct were as common among them as it is, in fact, rare.

We shall scarcely, therefore, be led into error if, in considering the preventive checks, we confine our attention to prudence, and assume that, as nothing but physical evil directly and immediately diminishes the longevity of mankind, nothing but an apprehended deficiency of some of the articles of wealth prevents their fecundity.

But though an apprehended deficiency of some of the articles of wealth is substantially the only preventive check to the increase of population, it is obvious that fear of the want of different articles operates, with all men, very differently; and even that an apprehended want of the same article will affect differently the minds of the individuals of different classes. An apprehended want of corn would produce on the minds of all Englishmen a very different effect from an apprehended want of silk. An apprehended want of butcher's meat would affect very differently the minds of Englishmen of different classes. It appears to us, therefore, convenient to divide for this purpose the articles of wealth into the three great classes of necessaries, decencies, and luxuries, and to explain the different effects produced by the fear of the want of the articles of wealth falling under each class. We must begin, however, by stating, as precisely as we can, what we mean by the words *necessaries, decencies, and luxuries;* terms which have been used ever since the Moral Sciences first attracted attention, but with little attention to precision or to consistent use.

It is scarcely necessary to remind our readers that these are relative terms, and that some person must always be assigned with reference to whom a given commodity or service is a luxury, a decency, or a necessary.

By *necessaries*, then, we express those things, the use of which is requisite to keep a given individual in the health and strength essential to his going through his habitual occupations.

By *decencies*, we express those things which a given individual must use in order to preserve his existing rank in society.

Every thing else of which a given individual makes use, or, in other words, all that portion of his consumption which is not essential to his health and strength, or to the preservation of his existing rank in society, we term *luxury*.

It is obvious that when consumed by the inhabitants of different Countries, or even by different individuals in the same Country, the same things may be either luxuries, decencies, or necessaries.

Shoes are necessaries to all the inhabitants of England. Our habits are such that there is not an individual whose health would not suffer from the want of them. To the lowest class of the inhabitants of Scotland they are luxuries: custom enables them to go barefoot without inconvenience and without degradation. When a Scotchman rises from the lowest to the middling classes of society, they become to him decencies. He wears them to preserve, not his feet, but his station in life. To the highest class, who have been accustomed to them from infancy, they are as much necessaries as they are to all classes in England. To the higher classes in Turkey wine is a luxury and tobacco a decency. In Europe it is the reverse. The Turk drinks and the European smokes, not in obedience, but in opposition both to the rules of health and to the forms of society. But wine in Europe and the pipe in Turkey are among the refreshments to which a

guest is entitled, and which it would be as indecent to refuse in the one Country as to offer in the other.

It has been said that the coal-heavers and lightermen, and some others among the hardworking London labourers, could not support their toils without the stimulus of porter. If this be true, porter is to them a necessary. To all others it is a luxury. A carriage is a decency to a woman of fashion, a necessary to a physician, and a luxury to a tradesman.

The question, whether a given commodity is to be considered as a decency or a luxury, is obviously one to which no answer can be given, unless the place, the time, and the rank of the individual using it be specified. The dress which in England was only decent a hundred years ago, would be almost extravagant now, while the house and furniture which now would afford merely decent accommodation to a gentleman, would then have been luxurious for a Peer. The causes which entitle a commodity to be called a necessary are more permanent and more general. They depend partly upon the habits in which the individual in question has been brought up, partly on the nature of his occupation, on the lightness or the severity of the labours and hardships that he has to undergo, and partly on the climate in which he lives.

Of these causes we have illustrated the two first by the familiar examples of shoes and porter. But the principal cause is climate. The fuel, shelter, and raiment, which are essential to a Laplander's existence, would be worse than useless under the Tropics. And as habits and occupations are very slowly changed, and climate suffers scarcely any alteration, the commodities which are necessary to the different classes of the inhabitants of a given district may, and generally do, remain for centuries unchanged, while their decencies and luxuries are continually varying.

Among all classes the check imposed by an apprehended deficiency of mere luxuries is but slight. The motives, perhaps we might say the instincts, that prompt the human race to marriage, are too powerful to be much restrained by the fear of losing conveniences unconnected with health or station in society. Nor is population much retarded by the fear of wanting mere necessaries. In comparatively uncivilized Countries, in which alone, as we have already seen, that want is of familiar occurrence, the preventive check has little operation. They see the danger, but want prudence and self-denial to be influenced by it. On the other hand, among nations so far advanced in civilization as to be able to act on such a motive, the danger that any given person or his future family shall actually perish from indigence appears too remote to afford any general rule of conduct.

The great preventive check is the fear of losing decencies, or, what is nearly the same, the hope to acquire, by the accumulation of a longer celibacy, the means of purchasing the decencies which give a higher social rank. When an Englishman stands hesitating between love and prudence, a family actually starving is not among his terrors; against actual want he knows that he has the fence of the poor-laws. But, however humble his desires, he cannot contemplate without anxiety a probability that the income which supported his social rank, while single, may be insufficient to maintain it when he is married; that he may be unable to give to his children the advantages of education which he enjoyed himself; in short, that he may lose his caste. Men of more enterprise are induced to postpone marriage, not merely by the fear of sinking, but also by the hope that in an unincumbered state they may rise. As they mount the horizon of their ambition keeps receding, until sometimes the time has passed for realizing those plans of domestic happiness which probably every man has formed in his youth.

It is by this desire of decencies, as distinguished from necessaries, that long-settled civilized Countries are preserved from the evils of a population greatly exceeding the means of comfortable subsistence. There are few triter subjects of declamation than the contrast between ancient simplicity and modern luxury. Few virtues, however useful, have received more applause than the contented and dignified poverty, the indifference to display, and the abstinence from unnecessary expense, which all refined nations attribute to their ancestors. Few vices, however mischievous, have been more censured than the ostentatious expenditure which every succeeding generation seems to consider its own characteristic.

It certainly seems at first sight that habits of unnecessary expenditure, as they have a tendency to diminish the wealth of an individual, must have the same effect on the wealth of a nation. And, separately considered, it appears clear that each act of unproductive consumption, whatever gratification it may afford to the consumer, must, *pro tanto*, impoverish the community. It is so much taken from the common stock and destroyed. And as the national capital is formed from the aggregate savings of individuals, it is certain that if each individual were to expend to the utmost extent of his means, the whole capital of the Country would be gradually wasted away, and general misery would be the result. But it appears equally certain that if each individual were to confine his expenditure to mere necessaries, the result would be misery quite as general and as intense.

We have seen that the powers of population, if not restrained by prudence, must inevitably produce almost every form of moral and physical evil. In the case which we are supposing, the wants of society would be confined to the food, raiment, and shelter essential to the support of existence; and they would all consist of the cheapest materials. At present, among civilized nations, the cultivation of the land employs only a portion of its inhabitants, and, generally speaking, as a nation increases in wealth, a smaller and smaller proportion; in England not one third; and a great part of the labourers so employed are producers of luxuries. Indeed, as potatoes afford a food five or six times as abundant as corn, and more than twenty times as abundant as meat, and, as far as can be judged by the appearance and powers of the lower Irish, quite as wholesome, meat and corn may be considered luxuries, to the extent in which they are more expensive than potatoes. Nor, consistently with the existence of private property, and of the desire of wealth, can the mode of cultivation be directed to the obtaining the largest possible return. The object is to obtain the largest return that is consistent with profitable farming, but, in the pursuit of this object, quantity of produce must often be sacrificed to economy of labour or time.

If there were no desire for any thing beyond necessaries, both the existing partition of the land, and the existing division of labour, would be varied. No family would wish to occupy more land than the small plot necessary to

afford them potatoes and milk. Supposing them to give to it the utmost nicety of garden cultivation, its management would still leave them time to produce the coarse manufactures necessary for their own use. The whole of the population would be agricultural. 761,348 families so employed at present in England, although their labour is far from being directed to the production of the greatest possible amount, provide, without much assistance from importation, subsistence for the whole of our 2,745,336 families. If all were so employed, and if quantity of produce were their sole object, it is probable that in ordinary seasons the soil of England, instead of fifteen millions, could feed at least sixty millions of people; and that of Europe, instead of two hundred, eight hundred millions. And that, in the absence of any checks more powerful than those experienced in the United States of America, the population of Europe might in fifty years amount to eight hundred millions. Indeed it is probable that, under the circumstances which we are supposing, the increase in Europe would be for a considerable time rather more rapid than that which has taken place in America. Preventive checks would not exist; marriages could not be hindered or even delayed by prudence, since there could be no reason to anticipate want; the habit of early marriages would put an end to profligacy; and, as all our habits would be eminently healthy, the positive checks would be reduced to their minimum.

So far the picture is rather pleasing; it exhibits a state of society, not rich certainly, nor refined, but supporting a very numerous population in health and strength, and in the full enjoyment of the many sources of happiness connected with early marriage. But it is obvious that this could not last for ever; it could not last indeed for two hundred and fifty years. By that time the population of Europe would amount to above three million millions; a number which the wildest imagination cannot conceive capable of existing simultaneously in the whole earth.

Sooner or later, therefore, the increase must be checked; and we have seen that prudence is the only check that does not involve vice or misery. But such is the force of the passions which prompt to marriage, and such is each man's reliance on his own good conduct and good fortune, that the evils, whatever they may be, the apprehension of which forms the prudential check, are frequently incurred. Where that evil is the loss of luxuries, or even of decencies, it is trifling in the first case, and bearable in the second. But, in the case which we are supposing, the only prudential check would be an apprehended deficiency of necessaries; and that deficiency, in the many instances in which it would actually be incurred, would be the positive check in its most frightful form. It would be incurred not only in consequence of that miscalculation of chances to which all men are subject, and certainly those not the least so who are anxious to marry, but through accidents against which no human prudence can guard. A *single* bad harvest may be provided against, but a succession of unfavourable seasons (and such successions do occur) must reduce such a people to absolute famine. When such seasons affect a nation indulging in considerable superfluous expenditure, they are relieved by a temporary sacrifice of that superfluity. The grain consumed in ordinary years by our breweries and distilleries is a store always at hand to supply a scarcity, and the same may be said of the large quantity of food raised for the support of domestic animals, but applicable to human subsistene. To these resources may be added the importation from abroad of necessaries instead of luxuries and the materials of luxury, of corn, for instance, instead of wine.

It may be said however, and indeed it has been said, that while the globe remains in its present irregularly occupied and irregularly cultivated state, emigration affords to all comparatively thickly-peopled nations a resource so ample and so easy as to render every prudential check to population unnecessary.

It is obvious that if capital and skill equal to those bestowed on the best parts of Flanders, or of the Scotch Lowlands, could be applied to the whole habitable world, a population ten times, perhaps one hundred times, perhaps even five hundred times as large could be maintained, as well, perhaps far better, than the one thousand millions now supposed to exist on its surface. It is possible, we will not say even that it is improbable, that in the course of centuries, or rather of hundreds of centuries, these splendid visions may be realized. But all experience shows that no numerous and civilized nation, surrounded by other civilized nations, can venture to rely on emigration as a permanent and adequate check to population. We say no numerous and civilized nation surrounded by other civilized nations; for we are aware that the hordes of Central Asia and of the Northern parts of Europe, and the surplus inhabitants of some small communities, such as the petty States of ancient Greece and Phœnicia, appear to have found, the one in colonization, the others in armed migrations, a periodical outlet; and that the Americans of European descent have enjoyed for centuries, and for centuries to come may enjoy, in the immense continent behind them, room for as rapid an increase of their numbers as the most unchecked propagation can supply. But these are not examples which Europe, as now constituted, can imitate. When all the land frontier is appropriated,—when invasion for the purpose of settlement is impossible, and the solitary traveller is repelled by a different language, different laws, different arts, and often a different religion,—when the other alternative is an expensive and distant voyage, and either an unsettled, and therefore in general an unwholesome country, or equal obstacles from variations of laws, language, religion, and arts, in a previously settled district,—when these are the difficulties to be encountered, no extensive and systematic emigration will be persisted in. Even the different parts of the same empire afford little assistance to one another, if difference of language, or habits, or considerable distance be interposed. The Austrian dominions contain some of the most thinly and some of the most thickly peopled portions of Europe; but Hungary is not colonized from the plains of Lombardy. If any European nation could hope to make emigration a complete substitute for prudence, that hope might be entertained by the inhabitants of the British Islands. We have the command of unoccupied continents in each hemisphere, the largest navy that the world ever saw to convey us to them, the largest capital that ever has been accumulated to defray the expense, and a population remarkable not merely for enterprise, but for enterprise of this particular description. These advantages we have enjoyed for centuries; almost from the times of the Tudors we have possessed a large outskirt of empire far exceeding in extent our European posses-

sions. And yet during this long period how little effect has emigration produced on our numbers! The swarms which we have sent out, and which we now send out, seem to be instantaneously replaced. We have founded one empire, and probably shall found many; but, after once a colony has been planted, its principal increase arises, not from the comparatively scanty recruits whom it receives from home, but from the unrepressed force of human fecundity.

In a future portion of this Treatise we shall explain with more detail the causes which impede emigration; at present we shall only repeat that all experience shows its inability to keep down the population of any large, well peopled, and tolerably civilized Country, such as Europe, China, or Hindostan. It appears, therefore, that habits of prudence in contracting marriage, and of considerable superfluous expenditure, afford the only permanent protection against a population pressing so closely on the means of subsistence as to be continually incurring the misery of the positive checks. And as the former habits exist only in a civilized, and the latter only in an opulent society, it appears equally clear that, as a nation advances in civilization and opulence, the positive checks are likely to be superseded by the preventive. If this be true, the evil of a redundant population, or, to speak more intelligibly, of a population too numerous to be adequately and regularly supplied with necessaries, is likely to diminish in the progress of improvement. As wealth increases, what were the luxuries of one generation become the decencies of their successors. Not only a taste for additional comfort and convenience, but a feeling of degradation in their absence, becomes more and more widely diffused. The increase in many respects of the productive powers of labour must enable increased comforts to be enjoyed by increased numbers: and as it is the more beneficial, so it appears to be the more natural course of events that increased comfort should not only accompany but rather precede increase of numbers.

But although we believe that, as civilization advances, the pressure of population on subsistence is a decreasing evil, we are far from denying the prevalence of this pressure in all long-settled Countries; indeed in all Countries except those which are the seats of colonies applying the knowledge of an old Country to an unoccupied territory. We believe that there are few portions of Europe the inhabitants of which would not now be richer if their numbers were fewer, and would not be richer hereafter if they were now to retard the rate at which their population is increasing. No plan for social improvement can be complete unless it embrace the means both of increasing the production of wealth and of preventing population from making a proportionate advance. The former is to be effected by legislative, the latter by individual prudence and forethought. The former must be brought about by the governing classes of society; the latter depends almost entirely on the lower. As a means of improvement, the latter is, on the whole, more efficient. It may be acted upon or neglected by almost every one. But, in the present state of public opinion and of commercial and fiscal policy in Europe, perhaps a greater progress may be made by insisting on the former. The statesman who neglects either considers only a portion of the subject.

But we must admit that ours are not the received opinions; or perhaps we ought to say, that our statement is opposed, on the one side or on the other, to the language used by almost every writer who has directly treated the subject of population. Almost every Economist will be found, in that part of his writings in which what has been called *the principle of population* is the immediate and principal question considered, to range himself under one of two hostile banners, each opposed not only to the other, but also to the doctrines which we have endeavoured to explain. On one side are those who believe that an increase of numbers is necessarily accompanied not merely by a positive, but by a relative increase of productive power; that density of population is the cause and the test of prosperity; and that, "were every nation under the sun to be released from all the natural and artificial checks on their increase, and to start off breeding at the fastest possible rate, many, very many generations must elapse before any necessary pressure could be felt." *

On the other side are those who maintain that population has a tendency (using the word tendency to express likelihood or probability) to increase beyond the means of subsistence; or, in other words, that, whatever be the existing means of subsistence, population is likely fully to come up to them, and even to struggle to pass beyond them, and is kept back principally by the vice and misery which that struggle must produce.

The whole of our previous remarks afford an answer to the first mentioned class of writers. We shall not therefore recur to them. The opinions of the other class we shall consider at some length: and we will begin by the following quotations from Mr. M'Culloch, Mr. Mill, and Mr. Malthus.

Among the valuable notes which Mr. M'Culloch has appended to his edition of the *Wealth of Nations*, one of the most interesting treats of population; and one of the objects of that note is to show that the population of the United States of America cannot continue to increase for any very considerable period at the rate at which it has increased during the last hundred years. We are perfectly convinced of the correctness of this anticipation; and we make the following extract not with any intention to oppose Mr. M'Culloch's opinions as to America, but because we are anxious to express our dissent to the form in which he lays down the general doctrine of population.

"It may be said perhaps," says Mr. M'Culloch, "that allowance must be made for the effects of the improvements which may be supposed to take place in agricultural science in the progress of society, or the possible introduction, at some future period, of new and more prolific species of crops. But it is easy to see that the influence of such improvements and changes must, supposing them to be realized in the fullest manner, be of very temporary duration; and that it cannot affect the truth of the principle, *that the power of increase in the human species must always, in the long run, prove an overmatch for the increase in the means of subsistence*. Suppose by some extraordinary improvement the quantity of food and other articles required for the subsistence and accommodation of man annually produced in Great Britain were suddenly doubled; the condition of all classes being in consequence signally improved, there would be less occasion for the exercise of moral

* Scrope, *Principles of Political Economy*, 1833, p. 276.

restraint; the period of marriage would therefore be accelerated, and such a powerful stimulus would be given to the principle of increase, *that in a very short period the population would be again on a level with the means of subsistence;* and there would also, owing to the change that must have been made in the habits of the people with respect to marriage, during the period that the population was rising to the level of the increased supply of food, be an extreme risk lest it should become too abundant, and produce an increased rate of mortality. Although, therefore, it is not possible to assign any certain limits to the progress of improvement, it is notwithstanding evident that it cannot continue for any considerable period to advance in the same proportion that population would advance supposing food were abundantly supplied. The circumstance of inferior lands, which require a greater outlay of capital and labour to make them yield the same supply as those that are superior, being invariably taken into cultivation in the progress of society, demonstrates, what is otherwise indeed sufficiently obvious to every one, that, in despite of improvements, the difficulty of adding to the supplies of food is progressively augmented as population becomes denser."

Mr. Mill's views are to be found in his discussion of wages. *Principles*, &c., ch. ii. s. 2. "If it were," he observes, "the natural tendency of capital (by which term Mr. Mill designates the instruments of labour, the materials on which they are to be employed, when produced by labour, and the subsistence of the labourer) to increase faster than population, there would be no difficulty in preserving the prosperous condition of the people. If, on the other hand, it were the natural tendency of population to increase faster than capital, the difficulty would be very great. There would be a perpetual tendency in wages to fall; the progressive fall of wages would produce a greater and a greater degree of poverty among the people, attended with its inevitable consequences, misery and vice. As poverty, and its consequent misery, increased, mortality would also increase: of a numerous family born, a certain number only, from want of the means of well being, would be reared. By whatever proportion the population tended to increase faster than capital, such a proportion of those who were born would die; the ratio of increase in capital and population would then remain the same, and the fall of wages would proceed no further. That population *has* a tendency to increase faster than, in most places, capital has actually increased, is proved incontestably by the condition of the population in most parts of the globe. In almost all Countries the condition of the great body of the people is poor and miserable. This would have been impossible, if capital had increased faster than population. In that case wages must have risen; and high wages would have placed the labourer above the miseries of want. This general misery of mankind is a fact which can be accounted for upon one only of two suppositions: either that there is a natural tendency in population to increase faster than capital, or that capital has, by some means, been prevented from increasing so fast as it has a tendency to increase. This, therefore, is an inquiry of the highest importance."

As the result of that inquiry, Mr. Mill decides the second alternative in the negative; and consequently conceives himself to have established the former, namely, that there is a natural tendency in population to increase faster than capital.

Mr. Malthus's opinions appear to have been considerably modified during the course of his long and brilliant philosophical career. In the first edition of his great Work the principle of population was represented as an insurmountable obstacle to the permanent welfare of the mass of mankind. And even in the last edition the following passages are open to the same construction

"There are few States in which there is not a constant effort in the population to increase beyond the means of subsistence. This constant effort as constantly tends to subject the lower classes of society to distress, and to prevent any great permanent amelioration of their condition. These effects, in the present state of society, seem to be produced in the following manner: —We will suppose the means of subsistence in any Country to be just equal to the easy support of its inhabitants. The constant effort towards population, which is found to act even in the most vicious societies, increases the number of people before the means of subsistence are increased. The food, therefore, which before supported eleven millions, must now be divided between eleven millions and a half. The poor consequently must live much worse, and many of them be reduced to severe distress. The number of labourers also being above the proportion of work in the market, the price of labour must tend to fall, while the price of provisions would at the same time tend to rise. The labourer therefore must do more work to earn the same as he did before. During this season of distress the discouragements to marriage and the difficulty of rearing a family are so great that the progress of population is retarded. In the mean time, the cheapness of labour, the plenty of labourers, and the necessity of an increased industry amongst them, encourage cultivators to employ more labour upon their land, to turn up fresh soil, and to manure and improve more completely what is already in tillage, till ultimately the means of subsistence may become in the same proportion to the population as at the period from which we set out. The situation of the labourer being then again tolerably comfortable, the restraints to population are in some degree loosened; and after a short period the same retrograde and progressive movements, with respect to happiness, are repeated." *Population*, book i. chap. 2. "According to the principle of population, the human race *has a tendency* to increase faster than food. It has, therefore, *a constant tendency* to people a Country fully up to the limits of subsistence; meaning, by these limits, the lowest quantity of food which will maintain a stationary population." Book iii. chap. i. note.

But when the opposite doctrine, namely, that, in the absence of disturbing causes, subsistence is likely to increase more rapidly than population, was brought before him by Mr. Senior, he appears to have disavowed, we will not say his former expressions, but the inferences to which they lead.

"The meaning," says Mr. Malthus, "which I intended to convey by the expression to which you object" (that population has a tendency to increase faster than food) "was, that population was always ready and inclined to increase faster than food, if the checks which repressed it were removed; and that

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though these checks might be such as to prevent population from advancing upon subsistence, or even to keep it at a greater distance behind, yet that, whether population were actually increasing faster than food, or food faster than population, it was true that, except in new colonies, favourably circumstanced, population was always pressing against food, and was always ready to start off at a faster rate than that at which the food was actually increasing."

"We are quite agreed that, in the capacity of reason and forethought, man is endowed with a power naturally calculated to mitigate the evils occasioned by the pressure of population against food. We are further agreed that, in the progress of society, as education and knowledge are extended, the probability is that these evils will practically be mitigated, and the condition of the labouring classes be improved."*

So explained, Mr. Malthus's opinions are opposed to the expressions of Mr. Mill and Mr. M'Culloch; his admission that, "in the progress of society, the probability is that the evils occasioned by the pressure of population against food will be mitigated," is opposed to Mr. M'Culloch's statement, "that the power of increase in the human species must always in the long run prove an overmatch for the increase in the means of subsistence;" and to Mr. Mill's, "that the tendency of population to increase faster than, in most places, capital has actually increased, is proved incontestably by the condition of the population in most parts of the globe." Archbishop Whately, with his usual acuteness, has in the following passage traced the question to a verbal ambiguity.

"The doctrine, that, since there is a tendency in population to increase faster than the means of subsistence, hence the pressure of population against subsistence may be expected to become greater and greater in each successive generation, (unless new and extraordinary remedies are resorted to,) and thus to produce a progressive diminution of human welfare—this doctrine, which some maintain in defiance of the fact that all civilized Countries have a greater proportionate amount of wealth now than formerly, may be traced chiefly to an undetected ambiguity in the word 'tendency,' which forms a part of the middle term of the argument. By a 'tendency' towards a certain result is sometimes meant, the existence of a cause which, operating unimpeded, would produce that result. In this sense it may be said, with truth, that the earth, or any other body moving round a centre, has a tendency to fly off at a tangent; (*i. e.*) the centrifugal force operates in that direction, though it is controlled by the centripetal; or, again, that man has a greater tendency to fall prostrate than to stand erect; (*i. e.*) the attraction of gravitation and the position of the centre of gravity are such that the least breath of air would overset him, but for the voluntary exertion of muscular force: and, again, that population has a tendency to increase beyond subsistence; (*i. e.*) there are in man propensities which, if unrestrained, lead to that result.

"But sometimes, again, 'a tendency towards a certain result' is understood to mean 'the existence of such a state of things that that result may be expected to take place.' Now it is in these two senses that the word is used, in the two premises of the argument in question. But in this latter sense, the earth has a greater tendency to remain in its orbit than to fly off from it; man has a greater tendency to stand erect than to fall prostrate; and (as may be proved by comparing a more barbarous with a more civilized period in the history of any Country) in the progress of Society, subsistence has a tendency to increase at a greater rate than population. In this Country, for instance, much as our population has increased within the last five centuries, it yet bears a far less ratio to subsistence (though still a much greater than could be wished) than it did five hundred years ago."*

It is obvious that if the present state of the world, compared with its state at our earliest records, be one of relative poverty, the tendency of population to increase more rapidly than subsistence must be admitted. If the means of subsistence continue to bear precisely the same proportion to the number of its inhabitants, it is clear that the increase of subsistence and of numbers has been equal. If its means of subsistence have increased much more than the number of its inhabitants, it is clear not only that the proposition in question is false, but that the contrary proposition is true, and that the means of subsistence have a natural tendency (using these words as expressing what is likely to take place) to increase faster than population. Now what is the picture presented by the earliest records of those nations which are now civilized, or, which is the same, what is now the state of savage nations?—a state of habitual poverty and occasional famine. A scanty population, but still scantier means of subsistence. Admitting, and it must be admitted, that in almost all Countries the condition of the great body of the people is poor and miserable, yet, as poverty and misery were their original inheritance, what inference can we draw from the continuance of that misery as to the tendency of their numbers to increase more rapidly than their wealth? But if a single Country can be found in which there is now less poverty than is universal in a savage state, it must be true that, under the circumstances in which that Country has been placed, the means of subsistence have a greater tendency to increase than the population. Now this is the case in every civilized Country. Even Ireland, the Country most likely to afford an instance of what has been called the tendency of things, poor and populous as she is, suffers less from want with her eight millions of people than when her only inhabitants were a few septs of hunters and fishers. In our own early history, famines, and pestilences, the consequences of famine, constantly recur. At present, though our numbers are trebled or quadrupled, they are unheard of.

The United States of America afford the best ascertained instance of great and continued increase of numbers. They have afforded a field in which the powers of population have been allowed to exhaust their energy; but, though exerted to their utmost, they have not as yet equalled the progress of subsistence. Whole colonies of the first settlers perished from absolute want; their successors struggled long against hardship and privation; but every increase of their number seems to have been accompanied or preceded by increased means of support. If it be conceded that there exists in the human race a natural tendency to advance from barbarism to civilization, and that the means of subsistence are proportionably more abundant in a civilized than in a

* *Appendix to* Senior's *Lectures on Population*, p. 61—82.

* Archbishop Whately, *Lectures on Political Economy. Lecture* 9.

savage state, and neither of these propositions can be denied, it must follow that there is a natural tendency in subsistence to increase in a greater ratio than population.

But although Mr. Malthus himself, in his earlier publications, has perhaps fallen sometimes into the exaggeration which is natural to a discoverer, the error, if he has committed one, does not affect the practical conclusions which place him, as a benefactor to mankind, on a level with Adam Smith. Whether, in the absence of disturbing causes, it be the tendency of subsistence or of population to advance with greater rapidity, is a question of slight importance, if it be acknowledged that human happiness or misery depend principally on their relative advance, and that there are causes, and causes within human control, by which that advance can be regulated. These are propositions which Mr. Malthus has established by facts and reasoning which, opposed as they were to long-rooted prejudice, and assailed by every species of sophistry and clamour, are now admitted by the majority of reasoners, and even by a large majority of those who take their opinions upon trust.

To explain what are the causes of the relative increase of subsistence and population is rather the business of a writer on politics than of a Political Economist. At present we will only say that knowledge, security of property, freedom of internal and external exchange, and equal admissibility to rank and power, are the principal causes which at the same time promote the increase of subsistence, and, by elevating the character of the people, lead them to keep at a slower rate the increase of their numbers. And that restrictions on exchange and commerce, artificial barriers excluding the great majority of the community from the chance of social eminence, and, above all, ignorance, and insecurity of person and property, are the general causes which both diminish the productiveness of labour, and tend to produce that brutal state of improvidence in which the power of increase, unchecked by prudence, is always struggling to pass the limits of subsistence, and is kept down only by vice and misery. We use the expression *general* causes, to exclude those causes which, being peculiar to certain nations, require separate consideration. Such are the superstitious desire of offspring in China, the political motives which formerly occasioned the creation of freeholders in Ireland, and the administration of the poor laws in some parts of England. But, omitting these details, it may be generally stated that all that degrades the character, or diminishes the productive power of a people, tends to diminish the proportion of subsistence to population, and *vice versâ*. And consequently that a population increasing more rapidly than the means of subsistence is, generally speaking, a symptom of misgovernment indicating deeper-seated evils, of which it is only one of the results.

And, notwithstanding the passages which we have cited, we believe these to be also the opinions of Mr. Mill and of Mr. M'Culloch. We believe that neither of these eminent writers doubts that the situation of the inhabitants of Europe has been gradually improving during the last 500 years. We believe that neither of them considers the improvement as having reached its limit, or as having any definite limit whatever. When they speak of the probable destinies of mankind, they teach the same doctrine as ourselves. It is only when separately discussing the subject of population that they have used the language to which we have ventured to object. We believe that they have used it without being misled by it themselves, and, perhaps on that very account, without perceiving its tendency to mislead others. But that those whose acquaintance with Political Economy is superficial (and they form the great mass of even the educated classes) *have* been misled by the form in which the doctrine of population has been expressed appears to us undeniable. When such persons are told that "it is the tendency of the human race to increase faster than food"—"to people a country fully up to the means of subsistence," they infer that what *has a tendency to happen* is to be expected. Because additional population *may* bring poverty, they suppose that it necessarily *will* do so: because increased means of subsistence *may* be followed and neutralized by a proportionate increase in the number of persons to be subsisted, they suppose that such *will* necessarily be the case. And unhappily there are many whom indolence, or selfishness, or a turn to despondency, make ready recipients of such a doctrine. It furnishes an easy escape from the trouble or expense implied by every project of improvement. "What use would it be," they ask, "to promote an extensive emigration? the whole vacuum would be immediately filled up by the necessary increase of population. Why should we alter the Corn Laws? If food were for a time more abundant, *in a very short period the population would be again on a level with the means of subsistence*, and we should be just as ill off as before."

There are many also, particularly among those who reason rather with their hearts than their heads, who are unable to assent to these doctrines, and yet believe them to be among the admitted results of Political Economy. Such persons apply to the whole Science the *argumentum ab absurdo*; and, instead of inquiring into the accuracy of the reasoning, refuse to examine the premises from which such objectionable conclusions are inferred.

It is because we believe these misconceptions to be extensively prevalent that we have ventured to detain our readers by this long discussion. A discussion which some may think a mere dispute about the more convenient use of a word, and others an attempt to prove a self-evident fact.

Production.

Production.

Having explained the sense in which we use the word wealth, and given an outline of the doctrine of population, we now proceed to consider production, or the means by which wealth is produced. The first terms to be defined are the verb *produce*, and the substantive *product*.

To produce, as far as Political Economy is concerned, *is to occasion an alteration in the condition of the existing particles of matter, for the occasioning of which alteration, or for the things thence resulting, something may be obtained in exchange.* This alteration is a *product*. It is scarcely necessary to remind our readers that matter is susceptible neither of increase nor diminution, and that all which man or any other agent of which we have experience can effect, is to alter the condition of its existing particles. But as Political Economy treats only of wealth, and therefore only of those alterations of which wealth is the result, we are forced to exclude all other alterations from the definition of products. The child who builds a castle

with sand on the shore, and the child who kicks it down, each occasions effects the same in kind as the man who builds or pulls down a palace; but as the exertions of the latter entitle him to be paid, he is properly said to *produce*, and the result of his conduct, whether it be the covering with buildings ground previously unoccupied, or rendering vacant what was previously built over, is properly called a product.

Products have been divided into material and immaterial, or, to express the same distinction in different words, into commodities and services. This distinction appears to have been suggested by Adam Smith's well-known division of labour into productive and unproductive. Those who thought the principle of that division convenient, feeling at the same time the difficulty of terming unproductive the labour without which all other labour would be inefficient, invented the term services, or immaterial products, to express its results.

It appears to us, however, that the distinctions that have been attempted to be drawn between productive and unproductive labourers, or between the producers of material and immaterial products, or between commodities and services, rest on differences existing not in the things themselves, which are the objects considered, but in the modes in which they attract our attention. In those cases in which our attention is principally called not to the act of occasioning the alteration, but to the result of that act, to the thing altered, Economists have termed the person who occasioned that alteration a productive labourer, or the producer of a *commodity* or material product. Where, on the other hand, our attention is principally called not to the thing altered, but to the act of occasioning that alteration, Economists have termed the person occasioning that alteration an unproductive labourer, and his exertions, *services*, or immaterial products. A shoemaker alters leather and thread and wax into a pair of shoes. A shoeblack alters a dirty pair of shoes into a clean pair. In the first case our attention is called principally to the things as altered. The shoemaker, therefore, is said to *make* or *produce* shoes. In the case of the shoeblack, our attention is called principally to the act as performed. He is not said to make or produce the commodity, clean shoes, but to perform the service of cleaning them. In each case there is of course an act and a result; but in the one case our attention is called principally to the act, in the other to the result.

Among the causes which direct our attention principally to the *act*, or principally to the *result*, seem to be, first, the degree of change produced; and secondly, the mode in which the person who benefits by that change generally purchases that benefit.

1. Where the alteration is but slight, especially if the thing that has been subjected to alteration still retains the same name, our attention is directed principally to the act. A cook is not said to *make* roast beef, but to *dress* it; but he is said to make a pudding, or those more elaborate preparations which we call *made* dishes. The change of name is very material: a tailor is said to *make* cloth into a coat; a dyer is not said to *make* undyed cloth into dyed cloth. The change produced by the dyer is perhaps greater than that produced by the tailor, but the cloth in passing through the tailor's hands changes its name; in passing through the dyer's it does not: the dyer has not produced a *new name*, nor, consequently, in our minds, a *new thing*.

The principal circumstance, however, is the mode in which the payment is made. In some cases the producer is accustomed to sell, and we are accustomed to purchase, not his labour, but the subject on which that labour has been employed; as when we purchase a wig or a chest of medicine. In other cases, what we buy is not the thing altered, but the labour of altering it, as when we employ a haircutter or a physician. Our attention in all these cases naturally fixes itself on the thing which we are accustomed to purchase; and according as we are accustomed to buy the labour, or the thing on which that labour has been expended,—as we are, in fact, accustomed to purchase a commodity or a service, we consider a commodity or a service as the thing produced. The ultimate object both of painting and of acting is the pleasure derived from imitation. The means adopted by the painter and the actor are the same in kind. Each exercises his bodily organs, but the painter exercises them to distribute colours over a canvass, the actor to put himself into certain attitudes, and to utter certain sounds. The actor sells his exertions themselves. The painter sells not his exertions, but the picture on which those exertions have been employed. The mode in which their exertions are sold constitutes the only difference between menial servants and the other labouring classes: a servant who carries coal from the cellar to the drawing-room performs precisely the same operation as the miner who raises them from the bottom of the pit to its mouth. But the consumer pays for the coals themselves when raised and received into his cellar, and pays the servant for the act of bringing them up. The miner, therefore, is said to produce the material commodity, coals; the servant the immaterial product, or service. Both, in fact, produce the same thing, an alteration in the condition of the existing particles of matter; but our attention is fixed in the one case on the act, in the other on the result of that act.

In the ruder states of society almost all manufactures are domestic: the Queens and Princesses of heroic times were habitually employed in overlooking the labours of their maidens. The division of labour has banished from our halls to our manufactories the distaff and the loom; and, if the language to which we have been adverting were correct, the division of labour must be said to have turned spinners and weavers from unproductive into productive labourers; from producers of immaterial services into producers of material commodities.

But objecting as we do to a nomenclature which should consider producers as divided, by the nature of their products, into producers of services and producers of commodities, we are ready to admit the convenience of the distinction between services and commodities themselves, and to apply the term *service* to the act of occasioning an alteration in the existing state of things, the term *commodity* to the thing as altered; the term *product* including both commodities and services.

It is to be observed that, in ordinary language, a person is not said to produce a thing unless he has employed himself for that especial purpose. If an English oyster-fisher should meet with an oyster containing a pearl, he would be called not the producer of the pearl, but its casual finder. But a Ceylon oyster-fisher, whose trade is to fish for pearl oysters, is called a producer of pearls. The *mere existence* of the pearls is in both cases owing to the agency of nature; their existence as articles of

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value is in both cases owing to the agency of the fisher in removing them from a situation in which they were valueless. In the one case he did this intentionally, in the other accidentally. Attention is directed in the one case to *his* agency, and *he* is therefore called the producer of the pearl. In the other case it is directed to the agency of nature, and he is called only the appropriator. But it appears to us the more convenient classification, for scientific purposes, to term him in both cases the producer.

Economists have in general opposed consumption to production. They have defined consumption to be the destruction wholly, or in part, of any portion of wealth. And they consider it as the ultimate object of all production.

*Tout ce qui est produit,** says M. Say, *est consommé; par conséquent, toute valeur créée est détruite, et n'a été créé que pour être détruite.*

"Consumption," says Mr. Malthus, "is the great purpose and end of all production."† "By consumption," says Mr. M'Culloch, "is meant the annihilation of those qualities which render commodities useful or desirable. To consume the products of Art and industry is to deprive the matter of which they consist of utility, and consequently of the exchangeable value communicated to it by labour. Consumption is, in fact, the end and object of human exertion, and when a commodity is in a fit state to be used, if its consumption be deferred, a loss is incurred."‡

That almost all that is produced is destroyed is true; but we cannot admit that it is produced for the purpose of being destroyed. It is produced for the purpose of being made use of. Its destruction is an incident to its use, not only not intended, but, as far as possible, avoided. In fact, there are some things which seem unsusceptible of destruction except by accidental injury. A statue in a gallery, or a medal, or a gem in a cabinet, may be preserved for centuries without apparent deterioration. There are others, such as food and fuel, which perish in the very act of using them, and hence, as these are the most essential commodities, the word consumption has been applied universally as expressing the making use of anything. But the bulk of commodities are destroyed by those numerous gradual agents which we call collectively *time*, and the action of which we strive to retard. If it be true that consumption is the object of all production, the inhabitant of a house must be termed its consumer, but it would be strange to call him its destroyer; since it would unquestionably be destroyed much sooner if uninhabited. It would be an improvement in the language of Political Economy if the expression "to use" could be substituted for that "to consume." There is, however, so much difficulty in changing an established nomenclature, that we shall continue to use the word consumption, premising that we use it to signify primarily the making use of a thing; a circumstance to which its destruction is generally, but not necessarily, incidental.

The wealth of a Country will much depend on the question, whether the tastes of its inhabitants lead them to prefer objects of slow or of rapid destruction.

It will depend, however, much more on their preference of productive or unproductive consumption.

Productive consumption is that use of a commodity which occasions an ulterior product. Unproductive consumption is, of course, that use which occasions no ulterior product. The characteristic of unproductive consumption is, that it adds to the enjoyment of no one but the consumer himself. Its only effect upon the rest of the community is to diminish *pro tanto* the mass of commodities applicable to their use.

Some commodities are unsusceptible of any but unproductive consumption; such are lace, embroidery, jewellery, and the other personal ornaments which are simply decorative, and afford neither warmth nor protection. Under this head may also be ranked tobacco and snuff, and the other stimulants, of which the best that can be said is, that they are not injurious. A much larger class of commodities is designed solely for productive use, and is never consumed unproductively, but by mistake. In this class are all tools, from the simplest to the most complicated; from the spade and the raft, to the steam engine and the Indiaman. But the generality of commodities may be used, according to the will of the proprietor, productively or unproductively; may be consumed so as to substitute some product in lieu of that which has been destroyed, or without any further beneficial result than the immediate pleasure which has accompanied their use. Whatever is capable of supporting human existence may be used to maintain those who are themselves producers, or those who are not. In the first case it is productively, in the second unproductively consumed.

The distinction between productive and unproductive *consumers* is less clearly marked than that between productive and unproductive *consumption*. To divide men into two classes, productive and unproductive consumers, would, in fact, be a false division, there being few who do not in some respects belong to both classes. So far as a man's consumption is essential to his production, he belongs to the first class; so far as it is not essential, to the second. Those only can be called simply unproductive who return nothing whatever for what they consume; those only simply productive who indulge in no superfluous consumption whatever.

To the first description belong those who, being provided, through their own previous exertions, or by the accidents of donation or inheritance, with a fund sufficient for their subsistence, are content to dedicate their revenue and their leisure to the purposes of mere enjoyment. This class is never large in any state of society. In an ignorant, and consequently a poor community, the number of those possessing a maintenance independent of exertion is necessarily small. Among civilized nations the love of accumulation, of power, of distinction, and of occupation, and the nobler desire of being more or less extensively useful, all powerfully counteract the slothful principles of our nature. As property becomes more secure, as the avenues to influence are opened, as merit and wealth rise in public estimation over the accidents of birth, as barbarous prejudices degrading to industry wear out, as the influence of sound religion teaches men that they were created for better purposes than selfish pleasure or useless mortification, in fact, as civilization improves, all the motives to voluntary exertion acquire force. And though the number of those who *might* live in idleness increases, the proportion of those who are unhappy enough to exercise that privilege diminishes.

Another class consists of those who derive their support solely from the spoil or the charity of others.

* Say, *Principles*, tome iii. p. 276.
† *Principles, &c.* p. 219.
‡ *Id.* p. 511—612. 2d Ed.

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The number of those who live by rapine has obviously a tendency to diminish in the progress of civilization. About mendicancy there may be some doubt, as some superfluous wealth seems necessary to its existence, and it may be supposed likely to increase with the superfluity on which it feeds. That laws ill framed or ill administered may allow it so to increase we know, from our own experience. But there seems to be no reason to doubt that, under a wise system of commercial and municipal legislation, the number of able-bodied paupers might be so reduced as to be practically unimportant.

The last class of unproductive consumers consists of those whom age or infirmity has rendered permanently incapable of production. We say *permanently*, to exclude children, and those suffering under temporary disability. Though a child or an invalid make no immediate return, their support is the necessary condition of their future services. This is by far the largest of the unproductive classes, and one not likely to suffer relative diminution, the same causes which tend to obviate disease and injury tending also to prolong life where their effects are incurable. But from the information collected in the House of Commons' Report on Friendly Societies, 5th July, 1825, vol. iv., we are inclined to think that in this Country the class in question cannot amount to a fortieth part, or about two and a half per cent. of the whole community.

The number of absolutely productive consumers, that is, of persons who consume solely for the purpose of reproducing, is much smaller. It may be a question indeed whether in a Country free from slavery, or regulations resembling slavery, any such class is to be found. The humblest labourer has some expenses which are not essential to his health and strength. We endeavour to give to our domestic animals nothing beyond what is strictly necessary, and in the Countries where man is considered as a domestic animal it might be expected that the consumption of a slave would be equally limited. But even the slave generally acquires some peculium, which implies that his ordinary subsistence somewhat exceeds his wants.

It appears from this analysis that the bulk of the community are neither productive nor unproductive consumers, but may be referred to the one class or to the other, according to the portion of their expenses for the time being under consideration. So far as the husbandman takes just enough of the least expensive food, is just sufficiently clad with the simplest raiment, and inhabits a dwelling just sufficiently weather-tight and spacious to protect him from the seasons, he is a productive consumer. But his pipe and his gin, and generally speaking his beer, and the humble ornaments of his person and his dwelling, form his unproductive consumption.

We do not, of course, mean it to be inferred that all personal expenditure beyond mere necessaries is necessarily unproductive. The duties of those who fill the higher ranks in society can seldom be well performed unless they conciliate the respect of the vulgar by a certain display of opulence. If a Judge, or an Ambassador, required by his station to support an establishment costing £2000 a year, should spend £4000, half of his consumption would be productive, and the other half unproductive. It would be a great mistake, however, to consider the third footman behind his coach, though a mere useless weight to the horses, an unproductive consumer. What the footman consumes are his wages, and, so far at least as he consumes them in order to enable himself to perform his services as footman, he is a productive consumer. The things unproductively consumed are his services, and *they* are consumed by his master. Nor is it to be supposed, on the other hand, that all consumption even of necessaries by those who are themselves producers, is a productive consumption. The half-employed pauper whose labour is worth £10 a year, and whose consumption is £20, consumes unproductively the difference.

Instruments of production.

Having explained the nature of production and consumption, we now proceed to consider the agents by whose intervention production takes place.

I. Labour.

The primary instruments of production are labour, and those agents of which nature, unaided by man, affords us the assistance.

Labour is the voluntary exertion of bodily or mental faculties for the purpose of production. It may appear unnecessary to define a term having a meaning so precise and so generally understood. Peculiar notions respecting the causes of value have, however, led some Economists to employ the term labour in senses so different from its common acceptation, that for some time to come it will be dangerous to use the word without explanation. We have already observed that many recent writers have considered value as solely dependent on labour. When pressed to explain how wine in a cellar, or an oak in its progress from a sapling to a tree, could, on this principle, increase in value, they replied that they considered the improvement of the wine and the growth of the tree as so much additional labour bestowed on each. We do not quite understand the meaning of this reply; but we have given a definition of labour, lest we should be supposed to include in it the unassisted operations of nature. It may also be well to remind our readers that this definition excludes all those exertions which are not intended, immediately or through their products, to be made the subjects of exchange. A hired messenger, and a person walking for his amusement, a sportsman, and a gamekeeper, the ladies at an English ball, and a company of Natch girls in India, undergo the same fatigues; but ordinary language does not allow us to consider those as undergoing labour who exert themselves for the mere purpose of amusement.

II. Natural agents.

Under the term "the agents offered to us by nature," or, to use a shorter expression, "natural agents," we include every productive agent so far as it does not derive its powers from the act of man.

The term "natural agent" is far from being a convenient designation, but we have adopted it partly because it has been already made use of in this sense by eminent writers, and partly because we have not been able to find one less objectionable. The principal of these agents is the land, with its mines, its rivers, its natural forests with their wild inhabitants, and, in short, all its spontaneous productions. To these must be added the ocean, the atmosphere, light and heat, and even those physical laws, such as gravitation and electricity, by the knowledge of which we are able to vary the combinations of matter. All these productive agents have in general, by what appears to be an inconvenient synecdoche, been designated by the term *land;* partly because the land, as a source of profit, is the most important of those which are susceptible of appropriation, but chiefly because its possession generally carries with it the com-

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mand over most of the others. And it is to be remembered that, though the powers of nature are necessary to afford a substratum for the other instruments of production to work upon, they are not of themselves, when universally accessible, causes of value. Limitation in supply is, as we have seen, a necessary constituent of value; and what is universally accessible is practically unlimited in supply.

III. Abstinence.

But although human labour, and the agency of nature, independently of that of man, are the primary productive powers, they require the concurrence of a third productive principle to give to them complete efficiency. The most laborious population, inhabiting the most fertile territory, if they devoted all their labour to the production of immediate results, and consumed its produce as it arose, would soon find their utmost exertions insufficient to produce even the mere necessaries of existence.

To the third principle, or instrument of production, without which the two others are inefficient, we shall give the name of *abstinence:* a term by which we express the conduct of a person who either abstains from the unproductive use of what he can command, or designedly prefers the production of remote to that of immediate results.

It was to the effects of this third instrument of production that we adverted when we laid down, as the third of our elementary propositions, that *the powers of labour and of the other instruments which produce wealth may be indefinitely increased by using their products as the means of further production.* All our subsequent remarks on abstinence are a developement and illustration of this proposition; we say developement and illustration, because it can scarcely be said to require formal proof.

The division of the instruments of production into three great branches has long been familiar to Economists. Those branches they have generally termed labour, land, and capital. In the principle of this division we agree; though we have substituted different expressions for the second and third branches. We have preferred the term natural agent to that of land, to avoid designating a whole genus by the name of one of its species: a practice which has occasioned the other cognate species to be generally slighted and often forgotten. We have substituted the term abstinence for that of capital on different grounds.

The term capital has been so variously defined that it may be doubtful whether it have any generally received meaning. We think, however, that, in popular acceptation, and in that of Economists themselves when they are not reminded of their definitions, that word signifies *an article of wealth, the result of human exertion, employed in the production or distribution of wealth.* We say the result of human exertion, in order to exclude those productive instruments to which we have given the name of natural agents, and which afford not profit, in the scientific sense of that word, but rent.

It is evident that capital, thus defined, is not a simple productive instrument; it is in most cases the result of all the three productive instruments combined. Some natural agent must have afforded the material, some delay of enjoyment must in general have reserved it from unproductive use, and some labour must in general have been employed to prepare and preserve it. *By the word abstinence, we wish to express that agent, distinct from labour and the agency of nature, the concurrence of which is necessary to the existence of capital, and which stands in the same relation to profit as labour does to wages.* We are aware that we employ the word abstinence in a more extensive sense than is warranted by common usage. Attention is usually drawn to abstinence only when it is not united with labour. It is recognised instantly in the conduct of a man who allows a tree or a domestic animal to attain its full growth; but it is less obvious when he plants the sapling or sows the seed corn. The observer's attention is occupied by the labour, and he omits to consider the additional sacrifice made when labour is undergone for a distant object. This additional sacrifice we comprehend under the term abstinence; not because abstinence is an unobjectionable expression for it, but because we have not been able to find one to which there are not still greater objections. We once thought of using "providence;" but providence implies no self-denial, and has no necessary connection with profit. To take out an umbrella is provident, but not in the usual sense of the word profitable. We afterwards proposed "frugality," but frugality implies some care and attention, that is to say, some labour; and though in practice abstinence is almost always accompanied by some degree of labour, it is obviously necessary to keep them separate in an analysis of the instruments of production.

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It may be said that pure abstinence, being a mere negation, cannot produce positive effects; the same remark might as well be applied to intrepidity, or even to liberty, but who ever objected to their being considered as equivalent to active agents? To abstain from the enjoyment which is in our power, or to seek distant rather than immediate results, are among the most painful exertions of the human will. It is true that such exertions are made, and indeed are frequent in every state of society, except perhaps in the very lowest, and have been made in the very lowest, for society could not otherwise have improved; but of all the means by which man can be raised in the scale of being, abstinence, as it is perhaps the most effective, is the slowest in its increase, and the least generally diffused. Among nations those that are the least civilized, and among the different classes of the same nation those which are the worst educated, are always the most improvident, and consequently the least abstinent.

Capital.

We have already defined capital to be an article of wealth, the result of human exertion, employed in the production or distribution of wealth, and we have observed that each individual article of capital is in general the result of a combination of all the three great instruments of production—labour, abstinence, and the agency of nature.

When a man has possessed himself of any article of wealth, and resolves to employ it, not for the mere purposes of enjoyment, but as capital, or, in other words, as a means of further production, or of distribution, there appear to be eight modes in which his design may be effected.

1. He may intentionally destroy it, in order to obtain the effects which are the direct consequences of its destruction. The consumption of gunpowder in a mine, and of coals in the furnace of a steam-engine, afford instances. The food which every producer must consume in order to keep himself in the health and strength necessary to enable him to continue a producer is also thus consumed.

2. He may retain it and employ it for purposes of which its gradual destruction is the incidental but not the intended, or, in all cases, the necessary consequence. All implements and machinery are thus employed.

3. He may vary its form, as when materials are converted into finished commodities.

4. He may simply retain it until its value has been increased by changes occasioned by the lapse of time, or by an altered state of the market. The proprietor of a vineyard who, immediately after an abundant vintage, retains his wine, aims at both these advantages.

5. He may keep it ready for sale to meet the wants of his customers. A shopkeeper's finished articles or stock in trade are thus employed.

6. He may give it to the proprietor of some natural agent for the use of that agent; as when a farmer pays rent to his landlord.

7. He may give it to a labourer in exchange for his exertions; or, in other words, he may employ it in the payment of wages.

8. He may give it in exchange for some other commodity, to be itself employed as capital; or, in other words, he may use it commercially.

Most capitalists employ portions of their capital in all these eight modes.

If we suppose a wine retailer's capital to consist of the knowledge which he has acquired during his education for his business, of the warehouse and the simple machinery necessary to his trade, of the stock of commodities necessary for his own current consumption, and of one hundred pipes of wine in wood and in bottle, we shall find that his knowledge, and machinery, and necessaries are destroyed without ever being directly exchanged: the only difference being, first, that his knowledge remains unimpaired until either his death or his retirement from business makes it suddenly valueless, while his buildings, and machinery, and clothes, furniture, and food are consumed and replaced at successive periods; and, secondly, that the destruction of his food is immediate, and that of his buildings, machinery, furniture, and clothing is gradual. We shall find that of the wine he retains a portion until it shall have been improved by age, and keeps a portion as stock in trade ready for immediate sale, but ultimately sells the whole and pays away its price, partly in rent for the land covered by his buildings, partly in wages to his clerks, porters, shopmen, and other labourers, partly in keeping up his buildings and machinery, and partly in the repurchase of wine, bottles, and corks to keep up the stock in his warehouse and shop. What remains of the price of his wine, and something must remain, or he would be in a worse situation than one of his own labourers, is generally termed his *profit:* a part of it he must employ in replacing the stock of commodities necessary to keep himself in health and strength; the remainder he may employ either in his own personal enjoyment and that of his friends, which is an unproductive use, or in the increase of his own capital, or in creating a capital for some other person, in the education, for instance, of his son, which are productive uses.

Adam Smith has divided capital into fixed and circulating.

"There are two ways," he observes, "in which a capital may be employed so as to yield a revenue or profit.

"First, it may be employed in raising, manufacturing, or purchasing goods, and selling them again with a profit. The capital employed in this manner yields no revenue or profit to its employer while it either remains in his possession or continues in the same shape. The goods of the merchant yield him no revenue or profit till he sells them for money, and the money yields him as little till it is again exchanged for goods. His capital is continually going from him in one shape, and returning to him in another, and it is only by means of such circulation, or successive exchanges, that it can yield him any profit. Such capitals, therefore, may properly be called *circulating* capitals.

"Secondly, it may be employed in the improvement of land, in the purchase of useful machines and implements of trade, or in such like things as yield a revenue or profit without changing masters or circulating any further. Such capitals, therefore, may properly be called *fixed* capitals.

"The capital of a merchant is altogether a circulating capital. He has occasion for no machines or instruments of trade, unless his shop or warehouse be considered as such.

"Some part of the capital of every master artificer or manufacturer must be fixed in the instruments of his trade. This part, however, is very small in some, and very large in others. A master tailor requires no other instruments of trade than a parcel of needles; those of a master shoemaker are a little, though but a little, more expensive.

"In other works a much greater fixed capital is required. In a great iron work, for example, the furnace, the forge, the slit mill, are instruments of trade which cannot be erected without a very great expense. That part of the capital of the farmer which is employed in the instruments of agriculture is a fixed, that which is employed in the wages and maintenance of his labouring servants is a circulating capital. He makes a profit of the one by keeping it in his own possession, and of the other by parting with it. A herd of cattle, bought in to make a profit by their milk and increase, is a fixed capital; the profit is made by keeping them. Their maintenance is a circulating capital; the profit is made by parting with it." Book ii. ch. i.

We are not aware that the principle of Adam Smith's division has ever been directly objected to. There may be some doubt, perhaps, whether the terms fixed and circulating are the best that could have been selected; but Adam Smith has stamped on them the meaning which he intended, and they have passed current in that signification ever since.

Mr. Ricardo, however, with the inattention to established usage which so much diminishes the usefulness of his writings, has used the terms fixed and circulating capital in a totally different sense. In this he has been followed by Mr. Mill; and as neither of these writers intimates that his use of the words is not the common one, it may be well to mark the difference.

"According as capital is rapidly perishable," says Mr. Ricardo, "and requires to be frequently reproduced, or is of slow consumption, it is classed under the heads of circulating or of fixed capital: a division not essential, and in which the line of demarcation cannot be accurately drawn. A brewer, whose buildings and machinery are valuable and durable, is said to employ a large portion of fixed capital; on the contrary, a shoemaker, whose capital is chiefly employed in the payment of wages, which are expended on food and clothing, commodities more perishable than buildings and machinery,

is said to employ a large proportion of capital as circulating capital. Ch. i. sec. 4.

Mr. Ricardo might well remark that the line of demarcation between his two sorts of capital cannot be accurately drawn; for what can be more vague, or more void of positive meaning, than such comparative terms as slow and rapid? The singular circumstance is that both he and Mr. Mill should have supposed, and it appears clear that they did suppose, that their division followed that of Adam Smith. It is obviously a cross division. The master tailor's needles which Adam Smith selects as an example of fixed capital, because the tailor retains them, would, according to Mr. Ricardo, be circulating, because they are perishable. On the other hand, the materials and stock in trade of an iron founder would be circulating capital according to Smith, and fixed according to Ricardo.

We may be able to make the nature of capital, and Adam Smith's conception of it, still clearer by quoting his subdivision of fixed and circulating capitals.

"Fixed capital," he says, "consists chiefly of the four following articles:

"First, of all useful machines and instruments of trade which facilitate and abridge labour.

"Secondly, of all buildings used for the purpose of trade or manufacture; such as shops, warehouses, and farm-buildings, &c. They are a sort of instruments of trade, and may be considered in the same light.

"Thirdly, of the improvements of land, of what has been profitably laid out in clearing, draining, enclosing, manuring, and reducing it into the condition most proper for culture. An improved farm may be regarded in the same light as one of those useful machines which facilitate and abridge labour.

"Fourthly, of the acquired and useful abilities of all the members of the society. The acquisition of such talents by the maintenance of the acquirer during his education, study, or apprenticeship, costs an expense, which is a capital fixed and realized, as it were, in his person. The improved dexterity of a workman may be considered in the same light as a machine or instrument of trade which facilitates and abridges labour.

"The circulating capital is composed likewise of four parts:

"First, of the money by means of which all the other three are circulated and distributed to their proper consumers.

"Secondly, of the stock of provisions in the possession of the butcher, the grazier, &c., for the purpose of sale.

"Thirdly, of the materials, whether altogether rude or more or less manufactured, of clothes, furniture, and building, which are not yet made up, but remain in the hands of the growers, manufacturers, or merchants.

"Fourthly, of the work which is made up and completed, but is still in the hands of the merchant or manufacturer; such as the finished work in the shops of the smith, the goldsmith, the jeweller, and the china merchant. The circulating capital consists, in this manner, of the provisions, materials, and finished work of all kinds which are in the hands of their respective dealers, and of the money that is necessary for circulating and distributing them to their final consumers." Book ii. c. i.

This enumeration contains, perhaps, some useless distinctions, and, we think, two improper exclusions, but, generally speaking, it gives an excellent view of the different species of capital.

The things which appear to be improperly excluded are, first, the necessaries of life, consumed by the labourer and the capitalist for their own support; and, secondly, the houses and other commodities of slow consumption which the owner lets out to the consumer.

Adam Smith can scarcely be said to have explained his reason for excluding from the term capital the necessaries in the possession of the labourer. He merely observes that the labourer consumes as sparingly as he can, and derives his revenue only from his labour. The attention of Mr. Malthus has been drawn to the subject; he agrees in this respect with Adam Smith, and on the following grounds:

"The only productive consumption, properly so called, is the consumption or destruction of wealth by *capitalists* with a view to reproduction. This is the only marked line of distinction which can be drawn between productive and unproductive consumption. The workman whom the capitalist employs consumes that part of his wages which he does not save, as revenue, with a view to subsistence or enjoyment; and not as capital with a view to production." *Definitions*, p. 258.

Mr. Malthus would admit that the coals in the furnace of a steam-engine are productively employed; because their consumption is the necessary condition to the engine's performing its work. And in what does the consumption of food by a labourer differ from that of coals by a steam-engine? Simply in this, that the labourer derives pleasure from what he consumes, and the steam-engine does not. If a labourer were so constituted as to feel no craving for food, and no gratification from eating, and were reminded of its necessity only by the debility consequent on its want, would not his meals, taken as they would be solely to enable him to undergo his fatigues, be productively consumed? Nature has wisely enforced an act of daily necessity by the stimulus of hunger, and the reward of enjoyment, but do that stimulus and enjoyment detract from its productiveness? Is the ploughman's dinner less the means of his toils because he considers it as their end? Is not the food of working cattle productively employed? Does not the owner of a West Indian estate consider the supplies which he sends to his slaves as a capital destined to productive consumption?

Adam Smith has stated at length his reasons for excluding from the term capital the houses and other articles which the owner lets out to the consumer.

"One portion," he states, "of the stock of a society is reserved for immediate consumption, of which the characteristic is that it affords no revenue or profit. The whole stock of mere dwelling-houses makes a part of this portion. If a house be let to a tenant, as the house itself can produce nothing, the tenant must pay the rent out of some other revenue which he derives either from labour, or stock, or land. Where masquerades are common, it is a trade to let out dresses for the night. Upholsterers frequently let furniture by the month or the year. The revenue, however, which is derived from such things must always be ultimately derived from some other source of revenue. A stock of clothes may last for several years; a stock of furniture half a century or a century; but a stock of houses, well built and properly taken care of, may last many centuries. Though the period of their total consumption, however, is more distant, they are still as really a stock reserved for immediate consumption as either clothes or furniture." Book ii. ch. i.

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This language would have been consistent if Adam Smith, like most of his successors, had confined the term capital to the instruments of further consumption. But we have seen that he includes under that term things incapable of productive consumption, if they have not reached the hands of those who are finally to use them. If a diamond necklace in a jeweller's shop be correctly termed capital, and Adam Smith has expressly stated that it is so, why is not a house which has been just finished by a speculative builder? It is difficult to perceive why he should have laid so much stress on the perishableness of the things in question. Perishableness and durability are not elements in the distinction between what is and what is not to be correctly termed capital. Many of the things which are used productively are of almost evanescent existence, such as the gas which lights a manufactory. On the other hand, the jewels of a noble family are not capital, though no limits can be assigned to their duration. It is at least conceivable that a house might be built so as not to require repair, and would this circumstance affect the question? In fact, however, the perishableness of these things is unfavourable to Adam Smith's view, as it shows their resemblance to things which he has admitted to be capital. A cellar of wine at a tavern-keeper's falls under his third class of circulating capitals; gradually the cellar is emptied, and when the last bottle has been drunk the capital is at an end. A house let ready furnished, a circulating library, a job carriage, a stage-coach, or a steam-packet, differs from the cellar of wine only because the progress of its consumption is less capable of being measured. Every day that it is used a portion wears away; and that portion is as much purchased and as much consumed by the hirer of the house or the carriage as the bottle of wine taken from the cellar. It is true that it may be consumed unproductively, and that in that case the hirer must pay the rent from some other revenue, as is the case with the price of *whatever* is unproductively consumed. But the portion of the house and furniture and carriage, for the time being unconsumed, is as much the capital, in the sense in which Adam Smith uses that word, of the upholsterer and the hackneyman, as the unconsumed portion of the wine is the capital of the tavern-keeper.

Capital may again be divided, according to the purposes to which it is applicable, into reproductive, simply productive, and unproductive.

We apply the term *reproductive* to all those articles of wealth which may be used to produce things of the same kind with themselves. All agricultural stock is reproductive; and so are all the necessaries of life. That portion of them which is consumed by the capitalists and labourers employed in producing necessaries is one of the means by which the regular supply is kept up. The coals in the furnace of a steam-engine used in working a coal mine, the iron instruments in an iron work, and a ship freighted with timber and naval stores are all reproductively employed.

We apply the term *simply productive* to those articles of wealth which, though instruments of production, cannot be employed in producing things of the same kind with themselves. A lace machine is simply productive. Its use is to make lace, but that lace cannot be employed to make a new machine. All the tools and machinery employed in the production of those things which cannot be productively consumed are themselves simply productive.

We apply the term *unproductive* or distributive capital to those commodities which are destined to unproductive use, but have not become the property of those who are to be their ultimate consumers.

A very great portion, perhaps the greater portion in value, of the commodities produced in an improved state of society, fall under this head at their first production.

We have already observed that, in every state of society, the number of absolutely unproductive *consumers* is small, and the number of absolutely productive consumers still smaller. But as wealth increases every man increases his unproductive *consumption*, until the whole amount in the whole society of such consumption may, and often does, exceed the whole amount of productive consumption. If we look through the shops of an opulent city we shall find the commodities destined to mere enjoyment far exceeding in value those destined to be employed in further production.

Some of Adam Smith's successors have excluded the things of which we are now speaking from the term capital. We have followed his example in including them, for two reasons.

First, because their exclusion is an unnecessary deviation from ordinary language. To say that a jeweller, with £50,000 worth of diamond ornaments in his shop, had no capital, would be an assertion of which few hearers would be able to guess the meaning.

But, in the second place, if it were possible to do, what certainly is much wanted, to form a new technical nomenclature for Political Economy, still we should include under the term capital the commodities in question. All Economists include under that term the materials and the instruments with which these commodities are formed. If the rough diamond and the gold in which it is to be set are capital while separate, it seems difficult to see what convenience there is in a nomenclature which denies them to be capital when united. Again, no Economist will doubt that a profit is received in proportion to the average time during which the commodities in question are retained by the capitalist. Why this profit is paid we shall endeavour to show hereafter, but the fact that it is paid may be assumed as unquestioned. But Economists are agreed that whatever gives a profit is properly termed capital.

The principal advantages derived from abstinence, or, to express the same idea in more familiar language, from the use of capital, are two: first the use of implements; and second the division of labour.

Implements, or tools, or machines (words which express things perhaps slightly different in some respects, but precisely similar so far as they are the subjects of Political Economy) have been divided into those which produce power, and those which transmit power. Under the first head are comprehended those which produce motion independently of human labour. Such are, for instance, those machines which are worked by the force of wind, of water, or of steam.

The second head comprises what are usually termed tools, such as the spade, the hammer, or the knife which assist the force, or save the time of the workman, but receive their impulse from his hand.

To these two classes a third must be added, including all those instruments which are not intended to produce or transmit motion, using that word in its popular sense. This class includes many things to which the name of implement, tool, or machine is not generally applied. A piece of land prepared for tillage, and the

corn with which it is to be sown, are among the implements by whose use the harvest is produced. Books and manuscripts are implements more productive than those invented by Arkwright or Brunel. Again, many of the things which popularly *are* called implements, such as the telescope, have no reference to motion; and others, such as a chain, or an anchor, or indeed any fastening whatever, are intended not to produce or transmit, but to prevent it.

The instruments which derive their impulse from the person who works them are in general of a simple description, and some of them are to be met with in the rudest state of human society. The first subsistence offered by nature to the savage consists of the brutes around him; but some instruments beyond the weapons which she has given to him must enable him to take advantage of her bounty.

It will be observed that we consider the use of all implements as implying an exercise of abstinence, using that word in our extended sense as comprehending all preference of remote to immediate results. In civilized society this appears to be strictly true. It is obviously true as to the *use* of all those instruments and materials which may be used at will, either for the purpose of present enjoyment, or for that of further production, such, for example, as the greater part of agricultural stock. It is equally true as to the *making* of all those implements which are incapable of any but productive use, such as tools and machinery in the popular acceptation of those words. In an improved state of society, the commonest tool is the result of the labour of previous years, perhaps of previous centuries. A carpenter's tools are among the simplest that occur to us. But what a sacrifice of present enjoyment must have been undergone by the capitalist who first opened the mine of which the carpenter's nails and hammer are the product! How much labour directed to distant results must have been employed by those who formed the instruments with which that mine was worked! In fact, when we consider that all tools, except the rude instruments of savage life, are themselves the product of earlier tools, we may conclude that there is not a nail, among the many millions annually fabricated in England, which is not to a certain degree the product of some labour for the purpose of obtaining a distant result, or, in our nomenclature, of some abstinence undergone before the Conquest, or perhaps before the Heptarchy.

The same remark applies to the acquired abilities which Adam Smith has properly considered a capital fixed and realized in the person of their possessor. In many cases they are the result of long previous exertion and expense on his own part; exertion and expense which might have been directed to the obtaining objects of immediate enjoyment, but which have, in fact, been undergone solely in the hope of a distant reward. And in almost all cases they imply much expense, and consequently much sacrifice of immediate enjoyment on the part of parents or guardians. The maintenance of a boy during the first eight or nine years of his life is indeed an unavoidable burthen, and therefore cannot be considered a sacrifice. But almost all that is expended on him after that age is voluntary. At nine or ten he might earn a maintenance in an agricultural, and more than a bare maintenance in a manufacturing employment, and at twenty-one obtain better wages than at any subsequent period of his life. But even the lowest department of skilled labour is in general inaccessible except at an expense very great, when we consider by whom it is to be borne; £15 or £20 is a low apprentice fee, but amounts to half the average annual income of an agricultural family. The greater part of the remuneration for skilled labour is the reward for the abstinence implied by a considerable expenditure on the labourer's education.

We must admit, however, that this reasoning does not apply to society in that rude state which is not perhaps within the scope of Political Economy. The savage seldom employs in making his bow or his dart time which he could devote to the obtaining of any object of immediate enjoyment. He exercises therefore labour and providence, but not abstinence. The first step in improvement, the rise from the hunting and fishing to the pastoral state, implies an exercise of abstinence. Much more abstinence, or, in other words, a much greater use of capital, is required for the transition from the pastoral to the agricultural state; and an amount not only still greater, but constantly increasing, is necessary to the prosperity of manufactures and commerce. An agricultural Country can remain stationary; a commercial and manufacturing one cannot. The capital which fifty years ago enabled England to be the first of commercial and manufacturing nations was probably far inferior in extent and efficiency to that now possessed by France, or even to that of the late Kingdom of the Netherlands. If our capital had remained stationary, we should have sunk to a second or third rate power. The same consequence might now follow if commercial restraints, or the waste of a long war, should check the increase of our present capital, while that of our rivals should continue progressive.

Having shown the connection between abstinence and the employment of implements, the next thing to be considered is the advantage which the use of implements affords. This subject, however, we shall pass over very briefly; partly because an attempt to give any thing like an adequate account of it, however concise, would far exceed the limits of this Treatise; partly because the subject has been considered at some length in the Articles in this Encyclopædia on MECHANICS and MANUFACTURES; and partly because we believe all our readers to be aware that the powers of man are prodigiously increased by the use of implements, though probably no man ever had, or ever will have, sufficient knowledge of details and perception of their relations and consequences, to estimate the whole amount of that increase. A few remarks on those instruments which produce motion, or, as it is technically termed, *power*, are all that we can venture on.

The superior productiveness of modern compared with ancient labour depends, perhaps, principally on the use of these instruments. We doubt whether all the exertions of all the inhabitants of the Roman Empire, if exclusively directed to the manufacture of cotton goods, could, in a whole generation, have produced as great a quantity as is produced every year by a portion of the inhabitants of Lancashire; and we are sure that the produce would have been generally inferior in quality. The only moving powers employed by the Greeks or Romans were the lower animals, water, and wind. And even these powers they used very sparingly. They scarcely used wind except to assist their merchant vessels in a timid coasting; they used rivers as they found them, for the purposes of communication, but did not connect them by canals; they used horses only for burthen and

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draught, and the latter without the assistance of springs. They made little use of that powerful machine to which we give the general name of a mill, in which a single shaft, turning under the impulse of animal power, or wind, or water, or steam, enables a child to apply a force equal sometimes to that of a thousand workmen.

A ship of the line under full sail has been called the noblest exhibition of human power: it is, perhaps, the most beautiful. But if dominion over matter, if the power of directing inanimate substances, at the same time to exert the most tremendous energy, and to perform the most delicate operations, be the test, that dominion and power are no where so strikingly shown as in a large cotton manufactory. One of the most complete which we have seen is that constructed by the late Mr. Marsland at Stockport; and, as it exhibits very strikingly both the power and the manageableness of machinery, it may be worth while to give a short description of it, as we saw it in 1825.

Mr. Marsland was the proprietor of the Mersey for about a mile of its course, and of a tongue of land which two reaches of the river form into a peninsula. Through the isthmus of this peninsula he bored a tunnel sufficient to receive seven wheels of large diameter, and to give passage to enough of the river to turn them; these wheels communicated rotatory motion to perpendicular shafts; and the perpendicular shafts communicated the same motion to numerous horizontal shafts connected with them by pinions. Each horizontal shaft ran below the ceiling of a work-room more than a hundred-feet long. The buildings connected with the wheels worked by the river contained six or seven stories of work-rooms, each supplied with its horizontal shaft. The rotatory motion was carried on from each horizontal shaft by means of small solid wheels called drums, affixed to the principal shaft of each detached piece of machinery, and connected with the great horizontal shaft of the work-room by a leathern strap. Many of these rooms were not occupied by Mr. Marsland himself. He let out, by the hour, the day, or the week, a certain portion of the floor of a work-room, and the liberty to make use of a certain portion of the horizontal shaft. The tenant placed his own machinery on the floor, connected its drum with the shaft that revolved rapidly above, and instantly saw his own small mechanical world, with its system of wheels, rollers, and spindles, in full activity, performing its motions with a quickness, a regularity, and, above all, a perseverance, far beyond the exertions of man. In the operation of machinery, power, like matter, seems susceptible of indefinite aggregation and of indefinite subdivision. In the performance of some of its duties the machinery moved at a rate almost formidable, in others at one scarcely perceptible. It took hold of the cotton of which a neckcloth was to be made, cleaned it, arranged its fibres longitudinally, twisted them into a strong and continuous thread, and finally wove that thread into muslin. It took the wool of which a coat was to be made, and, after subjecting it to processes more numerous than those which cotton experiences, at last wove it into cloth. For thousands of years, in fact from the last great convulsion which traced the course of the river, until Mr. Marsland bored his tunnel, had the Mersey been wasting all the energy that now works so obediently.

One of the most striking qualities of machinery is its susceptibility of indefinite improvement. On looking through the instructive evidence collected by the Committee on Artisans and Machinery, (1824,) it will be found that nothing is more impressed on the minds of the witnesses than the constant tide of improvement, rendering obsolete in a very few years all that might have been supposed to be perfect.

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Mr. Holdsworth, a spinner and machine-maker at Glasgow, states that the best mills at Glasgow are equal to the best mills at Manchester erected three or four years before. Mr. Holdsworth's history of his own proceedings will illustrate many of the previous observations.

He is asked whether he got his machinery from Manchester when he first commenced business. He replies: "I did not; I contemplated making it myself, and made the attempt, but there was so much difficulty in getting good workmen, and the expense of tools was so serious, that I desisted. I then selected a well-qualified young mechanic, and engaged him to make it for me. I gave over to him my patterns and my plans, and he executed well the machinery required in the first mill. Two years after I built a second mill, the machinery of which was also executed by him. After two years more I built a third and a larger mill, the machinery of which I made myself."

He is asked why he made the last machinery himself, and replies:

"In the first place that machine maker was very busy;" (it appears, subsequently, that, at the time of the examination, that maker could not have taken an order to execute any part of it under sixteen months, and that there were then eight or nine mills waiting for machinery, some of which had been ready for twelve months, and had only a small part of their machinery, and others had been ready six months and were empty:) "and as machine makers do not like to alter their plans, I could not prevail upon him to execute the improvements then recently made in Manchester." Fifth Report, p. 378.

Mr. J. Dunlop is asked (p. 473) how far he considers the American factories behind those of Glasgow. He replies, about thirty years. He goes on to state that they are in a progressive state, and the men very active and industrious. He is then asked whether, "supposing English machinery transported to America, with the assistance of English foremen, he does not think the population of America would soon be taught to work in their factories equally to the men of this Country!" He answers, "Yes, I think they would; but before they could acquire that we should be ahead of them a long way again. I reason comparing Scotland with England. We began the business of cotton-spinning later, we were of course behind, and we have always been behind; we have never been able to get up, and I believe never will."

Sixty years form a short period in the history of a nation; yet what changes in the state of England and the Southern parts of Scotland have the steam-engine and the cotton machinery effected within the last sixty years. They have almost doubled the population, more than doubled the wages of labour, and nearly trebled the rent of land. They enabled us to endure, not certainly without inconvenience, but yet to endure, a public debt more than trebled, and a taxation more than quadrupled. They changed us from exporters to importers of raw produce, and consequently changed our corn laws from a bounty on exportation to nearly a prohibition of importation. They have clad the whole world with a light and warm clothing, and made it so easy of ac-

quisition that we are perhaps scarcely aware of the whole enjoyment that it affords.

There appears no reason, unless that reason be to be found among our own commercial institutions, why the improvements of the next sixty years should not equal those of the preceding. The cotton machinery is far from perfection; the evidence which we have quoted shows that it receives daily improvements; and the steam-engine is in its infancy: its first application to vessels is within our recollection; its application to carriages has scarcely commenced; and it is probable that many other powers of equal efficiency lie still undiscovered among the secrets of nature, or, if known, are still unapplied. There are doubtless at this instant innumerable productive instruments known but disregarded because separately they are inefficient, and the effect of their combination has not been perceived. Printing and paper are both of high antiquity. Printing was probably known to the Greeks; it certainly was practised by the Romans, as loaves of bread stamped with the baker's initials have been found in Pompeii. And paper has been used in China from times immemorial. But these instruments separately were of little value. While so expensive a commodity as parchment, or so brittle a one as the papyrus, were the best materials for books, the sale of a number of good copies sufficient to pay the expense of printing could not be relied on. Paper without printing was more useful than printing without paper; but the mere labour necessary to constant transcription, even supposing the materials to be of no value, would have been such as still to leave books an expensive luxury. But the combination of these two instruments, each separately of little utility, has always been considered the most important invention in the history of man.

The second of the two principal advantages derived from abstinence, or, in other words, from the use of capital, is the division of labour.

We have already observed that division of production would have been a more convenient expression than division of labour; but Adam Smith's authority has given such currency to the term division of labour, that we shall continue to employ it, using it, however, in the extended sense in which it appears to have been used by Adam Smith. We say *appears* to have been used, because Smith, with his habitual negligence of precision, has given no formal explanation of his meaning. But in the latter part of his celebrated first chapter, he appears to include among the advantages derived from the division of labour all those derived from internal and external commerce. It is clear, therefore, that, by division of labour, he meant division of production, or, in other words, the confining as much as possible each distinct producer and each distinct class of producers to operations of a single kind.

The advantages derived from the division of labour are attributed by Smith to three different circumstances. "First, to the increase of dexterity in every particular workman; secondly, to the saving of the time which is commonly lost in passing from one species of work to another; and lastly, to the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many."

Smith was the first writer who laid much stress on the division of labour. The force and the variety of the examples by which he has illustrated it make the first chapter perhaps the most amusing and the best known in his whole Work. But, like most of those who have discovered a new principle, he has in some respects overstated, and in others understated, its effects. His remark, "that the invention of all those machines by which labour is so much facilitated and abridged seems to have been originally owing to the division of labour," is too general. Many of our most useful implements have been invented by persons neither mechanics by profession, nor themselves employed in the operations which those implements facilitate. Arkwright was, as is well known, a barber; the inventor of the power-loom is a clergyman. Perhaps it would be a nearer approach to truth if we were to say that the division of labour has been occasioned by the use of implements. In a rude state of Society, every man possesses, and every man can manage, every sort of instrument. In an advanced state, when expensive machinery and an almost infinite variety of tools have superseded the few and simple implements of savage life, those only can profitably employ themselves in any branch of manufacture who can obtain the aid of the machinery, and have been trained to use the tools, by which its processes are facilitated; and the division of labour is the necessary consequence. But, in fact, the use of tools and the division of labour so act and react on one another, that their effects can seldom be separated in practice. Every great mechanical invention is followed by an increased division of labour, and every increased division of labour produces new inventions in mechanism.

———————————*Alterius sic*
Altera poscit opem res et conjurat amice.

The increased dexterity of the workman, and the saving of the time which would be lost in passing from one sort of work to another, deserve the attention which they have received from Adam Smith. Both are consequences, and the first is a very important consequence of the division of labour. But he has passed by, or at least has not formally stated, other advantages derived from that principle which appear to be far more important.

One of the principal of these advantages arises from the circumstance that the same exertions which are necessary to produce a single given result are often sufficient to produce many hundred or many thousand similar results. The Post-office supplies a familiar illustration. The same exertions which are necessary to send a single letter from Falmouth to New York are sufficient to forward fifty, and nearly the same exertions will forward ten thousand. If every man were to effect the transmission of his own correspondence, the whole life of an eminent merchant might be passed in travelling, without his being able to deliver all the letters which the Post-office forwards for him in a single evening. The labour of a few individuals, devoted exclusively to the forwarding of letters, produces results which all the exertions of all the inhabitants of Europe could not effect, each person acting independently.

The utility of government depends on this principle. In the rudest state of society each man relies principally on himself for the protection both of his person and of his property. For these purposes he must be always armed, and always watchful; what little property he has must be movable, so as never to be far distant from its owner. Defence or escape occupy almost all his thoughts, and almost all his time, and, after all these

sacrifices, they are very imperfectly effected. "If ever you see an old man here," said an inhabitant of the confines of Abyssinia to Bruce, "he is a stranger; the natives all die young by the lance."

But the labour which every individual, who relies on himself for protection, must himself undergo is more than sufficient to enable a few individuals to protect themselves, and also the whole of a numerous community. To this may be traced the origin of governments. The nucleus of every government must have been some person who offered protection in exchange for submission. On the governor and those with whom he is associated, or whom he appoints. is devolved the care of defending the community from violence and fraud. And so far as internal violence is concerned, and that is the evil most dreaded in civilized society, it is wonderful how small a number of persons can provide for the security of multitudes. About fifteen thousand soldiers, and not fifteen thousand policemen, watchmen, and officers of Justice, protect the persons and property of the seventeen millions of inhabitants of Great Britain. There is scarcely a trade that does not engross the labour of a greater number of persons than are employed to perform this the most important of all services.

It is obvious, however, that the division of labour on which government is founded is subject to peculiar evils. Those who are to afford protection must necessarily be intrusted with power; and those who rely on others for protection lose, in a great measure, the means and the will to protect themselves. Under such circumstances, the bargain, if it can be called one, between the government and its subjects, is not conducted on the principles which regulate ordinary exchanges. The government generally endeavours to extort from its subjects, not merely a fair compensation for its services, but all that force or terror can wring from them without injuring their powers of further production. In fact, it does in general extort much more; for if we look through the world we shall find few governments whose oppression does not materially injure the prosperity of their people. When we read of African and Asiatic tyrannies, where millions seem themselves to consider their own happiness as dust in the balance compared with the caprices of their despot, we are inclined to suppose the evils of misgovernment to be the worst to which man can be exposed. But they are trifles compared to those which are felt in the absence of government. The mass of the inhabitants of Egypt, Persia, and Burmah, or to go as low as perhaps it is possible, the subjects of the Kings of Dahomi and Ashantee, enjoy security, if we compare their situation with that of the ungoverned inhabitants of New Zealand. So strongly is this felt that there is no tyranny which men will not eagerly embrace, if anarchy is to be the alternative. Almost all the differences between the different races of men, differences so great that we sometimes nearly forget that they all belong to the same species, may be traced to the degrees in which they enjoy the blessings of good government. If the worst government be better than anarchy, the advantages of the best must be incalculable. But the best governments of which the world has had experience, those of Great Britain and of the Countries which have derived their institutions from Great Britain, are far from having attained the perfection of which they appear to be susceptible. In these governments the subordinate duties are generally performed by persons specially educated for these purposes, the superior ones are not. It seems to be supposed that a knowledge of politics, the most extensive and the most difficult of all Sciences, is a natural appendage to persons holding a high rank in society, or may be acquired at intervals snatched from the bustle and the occupation of laborious and engrossing professions. In despotisms, the principal evils arise partly from the ignorance, and partly from the bad passions of the rulers. In representative governments, they arise principally from their unskilfulness. It is to be hoped that a further application of the division of labour, the principle upon which all government is founded, by providing an appropriate education for those who are to direct the affairs of the State, may protect us as effectually against suffering under ignorance or inexperience in our governors, as we are now protected against their injustice.

Another important consequence of the division of labour, and one which Adam Smith, though he has alluded to it, has not prominently stated, is the power possessed by every nation of availing itself, to a certain extent, of the natural and acquired advantages of every other portion of the commercial world. Colonel Torrens is the first writer who has expressly connected foreign trade with the division of labour, by designating international commerce as "the territorial division of labour."

Nature seems to have intended that mutual dependence should unite all the inhabitants of the earth into one commercial family. For this purpose she has indefinitely diversified her own products in every climate and in almost every extensive district. For this purpose, also, she seems to have varied so extensively the wants and the productive powers of the different races of men. The superiority of modern over ancient wealth depends in a great measure on the greater use we make of these varieties. We annually import into this Country about thirty million pounds of tea. The whole expense of purchasing and importing this quantity does not exceed £2,250,000, or about 1*s.* 6*d.* a pound, a sum equal to the value of the labour of only forty-five thousand men, supposing their annual wages to amount to £50 a year. With our agricultural skill, and our coal mines, and at the expense of above 40*s.* a pound instead of 1*s.* 6*d.*, that is, at the cost of the labour of about one million two hundred thousand men instead of forty-five thousand, we might produce our own tea, and enjoy the pride of being independent of China. But one million two hundred thousand is about the number of all the men engaged in agricultural labour throughout England. A single trade, and that not an extensive one, supplies as much tea, and that probably of a better sort, as could be obtained, if it were possible to devote every farm and every garden to its domestic production.

The greater part of the advantage of rather importing than growing and manufacturing tea arises, without doubt, from the difference between the climates of China and England. But a great part also arises from the different price of labour in the two Countries. Not only the cultivation of the tea plant, but the preparation of its leaves, requires much time and attention. The money wages of labour are so low in China, that these processes add little to the money cost of the tea. In England the expense would be intolerable. When a nation, in which the powers of production, and con-

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sequently the wages of labour, are high, employs its own members in performing duties that could be as effectually performed by the less valuable labour of less civilized nations, it is guilty of the same folly as a farmer who should plough with a race-horse.

Another important consequence of the division of labour is the existence of retailers: A class who, without being themselves employed in the direct production of raw or manufactured commodities, are, in fact, the persons who supply them to their ultimate purchasers, and that at the times and in the portions which the convenience of those purchasers requires. When we look at a map of London and its suburbs, and consider that that province covered with houses contains more than a tenth of the inhabitants of England, and consumes perhaps one-fifth in value of all that is consumed in England, and obtains what it consumes, not from its own resources, but from the whole civilized world, it seems marvellous that the daily supply of such multitudes should be apportioned with any thing like accuracy to their daily wants. It is effected principally by means of the retailers. Each retailer, the centre of his own system of purchasers, knows, by experience, the average amount of their periodical wants. The wholesale dealer, who forms the link between the actual producer or importer, and the retailer, knows also, by experience, the average amount of the demands of his own purchasers, the retailers; and is governed by that experience in purchasing himself from the importer or producer. And the average amount of these last purchases affords the data on which the importers and producers regulate the whole vast and multifarious supply. It can scarcely be necessary to dwell on the further advantages derived from the readiness and subdivision of the retailer's stock; or, to point out the convenience of having to buy a steak from a butcher, instead of an ox from a grazier. These are the advantages to which we formerly referred, as enabling the retailer to obtain a profit proportioned to the average time during which his stock in trade remains in his possession.

We now proceed to show that the division of labour is mainly dependent on Abstinence, or, in other words, on the use of Capital.

"In that rude state of society," says Adam Smith, "in which there is no division of labour, in which exchanges are seldom made, and in which every man provides every thing for himself, it is not necessary that any stock should be accumulated or stored up beforehand in order to carry on the business of the society. Every man endeavours to supply, by his own industry, his own occasional wants as they occur. When he is hungry, he goes to the forest to hunt; when his coat is worn out, he clothes himself with the skin of the first large animal he kills; and when his hut begins to go to ruin, he repairs it as well as he can with the trees and the turf that are nearest to it.

"But when the division of labour has once been thoroughly introduced, the produce of a man's own labour can supply but a very small part of his occasional wants. The far greater part of them are supplied by the produce of other men's labour, which he purchases with the produce, or, what is the same thing, with the price of the produce of his own. But his purchase cannot be made until such time as the produce of his own labour has not only been completed, but sold. A stock of goods of different kinds, therefore, must be stored up somewhere, sufficient to maintain him, and to supply him with the materials and tools of his work, till such time, at least, as both these events can be brought about. A weaver cannot apply himself entirely to his peculiar business, unless there is beforehand stored up somewhere, either in his own possession, or in that of some other person, a stock sufficient to maintain him, and to supply him with the materials and tools of his work, till he has not only completed, but sold his web. This accumulation must evidently be previous to his applying his industry for so long a time to such a peculiar business." *Wealth of Nations*, book ii. *Introduction.*

Perhaps this is inaccurately expressed; there are numerous cases in which production and sale are contemporaneous. The most important divisions of labour are those which allot to a few members of the community the task of protecting and instructing the remainder. But their services are sold as they are performed. And the same remark applies to almost all those products to which we give the name of services. Nor is it absolutely necessary in any case, though, if Adam Smith's words were taken literally, such a necessity might be inferred, that, before a man dedicates himself to a peculiar branch of production, a stock of goods should be stored up to supply him with subsistence, materials, and tools, till his own product has been completed and sold. That he must be kept supplied with those articles is true; but they need not have been stored up before he first sets to work, they may have been produced while his work was in progress. Years must often elapse between the commencement and sale of a picture. But the painter's subsistence, tools, and materials for those years are not stored up before he sets to work: they are produced from time to time during the course of his labour. It is probable, however, that Adam Smith's real meaning was, not that the identical supplies which will be wanted in a course of progressive industry must be already collected when the process which they are to assist or remunerate is about to be begun, but that a fund or source must then exist from which they may be drawn as they are required. That fund must comprise in specie some of the things wanted. The painter must have his canvass, the weaver his loom, and materials, not enough, perhaps, to complete his web, but to commence it. As to those commodities, however, which the workman subsequently requires, it is enough if the fund on which he relies is a productive fund, keeping pace with his wants, and virtually set apart to answer them.

But if the employment of capital is required for the purpose of allowing a single workman to dedicate himself to one pursuit, it is still more obviously necessary in order to enable aggregations, or classes of producers, to concur, each by his separate exertions, in one production. In such cases even the mere matter of distribution, the mere apportionment of the price of the finished commodity among the different producers requires the employment of a considerable capital, and for a considerable time, or, in other words, a considerable exertion of abstinence. The produce of independent labour belongs by nature to its producer. But where there has been a considerable division of labour, the product has no *one* natural owner. If we were to attempt to reckon up the number of persons engaged in producing a single neckcloth, or a single piece of lace, we should find the number amount to many thousands; in fact, to many tens of thousands. It is obviously impossible that all these persons, even if they could ascertain their

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respective rights as producers, should act as owners of the neckcloth or the lace, and sell it for their common benefit.

This difficulty is got over by distinguishing those who assist in production by advancing capital, from those who contribute only labour—a distinction often marked by the terms master and workman; and by arranging into separate groups the different capitalists and workmen engaged in distinct processes, and letting each capitalist, as he passes on the commodity, receive from his immediate successor the price both of his own abstinence and of his workmen's labour.

It may be interesting to trace this process in the history of a coloured neckcloth or a piece of lace. The cotton of which it is formed may be supposed to have been grown by some Tenessee or Louisiana planter. For this purpose he must have employed labourers in preparing the soil and planting and attending to the shrub for more than a year before its pod ripened. When the pod became ripe, considerable labour, assisted by ingenious machinery, was necessary to extricate the seeds from the wool. The fleece thus cleaned was carried down the Mississippi to New Orleans, and there sold to a cotton factor. The price at which it was sold must have been sufficient, in the first place, to repay to the planter the wages which had been paid by him to all those employed in its production and carriage; and, secondly, to pay him a profit proportioned to the time which had elapsed between the payment of those wages and the sale of the cotton; or, in other words, to remunerate him for his abstinence in having so long deprived himself of the use of his money, or of the pleasure which he might have received from the labour of his work-people, if, instead of cultivating cotton, he had employed them in contributing to his own immediate enjoyment. The New Orleans factor, after keeping it perhaps five or six months, sold it to a Liverpool merchant. Scarcely any labour could have been expended on it at New Orleans, and, in the absence of accidental circumstances, its price was increased only by the profit of the cotton factor. A profit which was the remuneration of his abstinence in delaying, for five or six months, the gratification which he might have obtained by the expenditure on himself of the price paid by him to the planter. The Liverpool merchant brought it to England and sold it to a Manchester spinner. He must have sold it at a price which would repay, in the first place, the price at which it was bought from the factor at New Orleans; in the second place, the freight from thence to Liverpool; (which freight includes a portion of the wages of the seamen, and of the wages of those who built the vessel, of the profits of those who advanced those wages before the vessel was completed, of the wages and profits of those who imported the materials of which that vessel was built, and, in fact, of a chain of wages and profits extending to the earliest dawn of civilization;) and, thirdly, the merchant's profit for the time that these payments were made before his sale to the manufacturer was completed.

The spinner subjected it to the action of his work-people and machinery, until he reduced part of it into the thread applicable to weaving muslin, and part into the still finer thread that can be formed into lace.

The thread thus produced he sold to the weaver and to the lacemaker; at a price repaying, in addition to the price that was paid to the merchant, first, the wages of the work-people immediately engaged in the manufacture; secondly, the wages and profits of all those who supplied, by the labour of previous years, the buildings and machinery; and, thirdly, the profit of the master spinner. It would be tedious to trace the transmission of the thread from the weaver to the bleacher, from the bleacher to the printer, from the printer to the wholesale warehouseman, from him to the retailer, and thence to the ultimate purchaser; or even its shorter progress from the lacemaker to the embroiderer, and thence to the ultimate purchaser. At every step a fresh capitalist repays all the previous advances, subjects the article, if unfinished, to further processes, advances the wages of those engaged in its further manufacture and transport, and is ultimately repaid by the capitalist next in order all his own advances, and a profit proportioned to the time during which he has abstained from the unproductive enjoyment of the capital thus employed.

It will be observed, that we have not mentioned the taxation that must have been incurred throughout the whole process which we have described, or the rent that must have been paid for the use of the various appropriated natural agents whose services were requisite or beneficial. We have left rent unnoticed, because its amount depends so much on accident that any further allusion to it would have much increased the complexity of the subject. We have not expressly mentioned taxation, because it is included under the heads which we have enumerated. The money raised by taxation is employed in paying the wages and profits of those who perform, or cause to be performed, the most important of all services, the protecting the community from fraud and violence. Those who are thus employed afford precisely the same assistance to the merchant or the manufacturer, as the private watchman who protects the warehouse, or the smith who fortifies it with bars and padlocks.

Our limits prohibit our attempting to trace the gradual increase of the value of a pound of cotton from the time it was gathered on the banks of the Mississippi, till it appears in a Bond Street window as a piece of elaborate lace. We should probably be understating the difference if we were to say that the last price was a thousand times the first. The price of a pound of the finest cotton wool, as it is gathered, is less than two shillings. A pound of the finest cotton lace might easily be worth more than a hundred guineas. No means, except the separation of the functions of the capitalist from those of the labourer, and the constant advance of capital from one capitalist to another, could enable so many thousand producers to direct their efforts to one object, to continue them for so long a period, and to adjust the reward for their respective sacrifices.

Productiveness of Labour in Agriculture and Manufactures. Fourth Elementary Proposition.

Productiveness of labour in agriculture and manufactures.

Before we quit the subject of production, it is necessary to explain an important difference between the efficiency of the different productive instruments when employed in cultivating the earth, and their efficiency when employed in preparing for human use the raw produce obtained by agriculture: or, in other words, between the efficiency of agricultural and manufacturing industry. In the course of this discussion we shall illustrate the last of the four elementary propositions on which we believe the Science of Political Economy to rest; namely,

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that, *agricultural skill remaining the same, additional labour employed on the land within a given district produces in general a less proportionate return.*

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The difference between the efficiency of agricultural and of manufacturing industry which we have now to consider, consists in the power which agricultural industry possesses, and manufacturing industry does not possess, of obtaining an additional product from the same materials. We have seen that the use of implements and the division of labour assist the exertions of man to an extent quite incalculable at present, and apparently capable of indefinite increase. But manufacturing improvements, though they enable one man to do the work of hundreds or of thousands,—though they enable the same amount of labour employed on the same materials to produce a more and more useful commodity, cannot enable the same amount of labour, or even increased labour, employed on the same quantity of *materials*, to produce a much larger amount of finished work of the same quality, than could have been produced before. If the labour and the skill now employed throughout England on the manufacture of cotton were doubled, but the quantity of raw materials remained the same, the quantity of manufactured produce could not be sensibly increased. The value of that produce might perhaps be much increased, it might be made much finer, and consequently of greater length or breadth; but supposing the quality of the produce unaltered, its quantity could be increased only by the saving which might be made of that small portion of the raw material which now is wasted.

The case of agriculture is different. Those regions, indeed, which lie within the limits of perennial snow, or consist of rock or loose sand, or precipitous mountain, are unsusceptible of improvement. But with these exceptions, the produce of every extensive district seems capable of being almost indefinitely increased by constantly increasing the labour bestowed on it. Nothing appears more hopelessly barren than an extensive bog with its black-looking pools and rushy vegetation. But, by draining, by burning the limestone on which, in Ireland at least, it generally rests, and by employing the lime to convert the matted fibres of the turf into a vegetable mould, the bog may be made not only productive but fertile. There are about thirty-seven millions of acres in England and Wales. Of these it has been calculated that not eighty-five thousand, less in fact than one four-hundredth part, are in a state of high cultivation, as hop grounds, nursery grounds, and fruit and kitchen gardens; and that five millions are waste. All that is not waste is productively employed, but how small is its produce compared to the amount to which unlimited labour and abstinence might raise it! If the utmost use were made of lime and marl and the other mineral manures; if by a perfect system of drainage and irrigation water were nowhere allowed to be excessive or deficient; if all our wastes were protected by enclosures and planting, if all the land in tillage, instead of being scratched by the plough, were deeply and repeatedly trenched by manual labour; if minute care were employed in the selecting and planting of every seed or root, and watchfulness sufficient to prevent the appearance of a weed; if all live stock, instead of being pastured, had their food cut and brought to them; in short, if the whole Country were subjected to the labour which a rich citizen lavishes on his patch of suburban garden; if it were possible that all this should be effected, the agricultural produce of the Country might be raised to ten times, or indeed to much more than ten times its present amount. No additional labour or machinery can work up a pound of raw cotton into more than a pound of manufactured cotton; but the same bushel of seed-corn, and the same rood of land, according to the labour and skill with which they are treated, may produce four bushels, or eight bushels, or sixteen.

But although the land in England is capable of producing ten times, or more than ten times as much as it now produces, it is probable that its present produce will never be quadrupled, and almost certain that it will never be decupled.

On the other hand, unless our manufactures be checked by war, or by the continuance or introduction of legislative enactments unfavourable to their progress, their produce may increase during the next century at the same rate, or at a still greater rate, than it increased during the last century. It may be quadrupled, or much more than quadrupled.

The advantage possessed by land in repaying increased labour, though employed on the same materials, with a constantly increasing produce, is overbalanced by the diminishing proportion which the increase of the produce generally bears to the increase of the labour. And the disadvantage of manufactures in requiring for every increase of produce an equal increase of materials, is overbalanced by the constantly increasing facility with which the increased quantity of materials is worked up.

A century ago the average annual import of cotton wool into Great Britain was about one million two hundred thousand pounds. The amount now annually manufactured in Great Britain exceeds two hundred and forty millions of pounds. But though the materials now manufactured are increased at least two hundred times, it is obvious that the labour necessary to manufacture them has not increased two hundred times. It may be doubted whether it has increased thirty times. The whole number of families in Great Britain, exclusively of those employed in agriculture, amounted, at the enumeration in 1831, to 2.453,011; if we suppose the transport, manufacture, and sale of cotton to employ about one-eighth of them, or about 300,000 families, it is a large allowance. But with the inefficient machinery in use a century ago, the annual manufacture of one million two hundred thousand pounds of cotton could not have required the annual labour of less than ten thousand families. It probably required many more. The result has been that, although we now require two hundred times as much of the raw material as was required a century ago, and although that additional quantity of raw material is probably obtained from the soil by more than two hundred times the labour that was necessary to obtain the smaller quantity, yet, in consequence of the diminution of the labour necessary to manufacture a given amount, the price of the manufactured commodity (a price which exhibits the sum of the labour necessary for both obtaining the materials and working them up) has constantly diminished. In 1786, when our annual import was about twenty millions of pounds of cotton wool, the price of the yarn denominated No. 100 was 38*s*. a pound. In 1792, when the import amounted to thirty-four millions of pounds, the price of the same yarn was 16*s*. a pound. In 1806, when the import amounted to sixty millions, the price of the yarn had fallen to 7*s*. 2*d*. a pound; and with the increased quantity manufactured, it has now fallen below 3*s*. a pound. Every increase in the quantity manufactured has been

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accompanied by improvements in machinery, and an increased division of labour, and their effects have much more than balanced any increase which may have taken place in the proportionate labour necessary to produce the raw material.

The proposition that, in agriculture, additional labour generally produces a less proportionate result, or, in other words, that the labour of twenty men employed on the land within a given district, though it will certainly produce more than that of ten men, will seldom produce twice as much, will be best illustrated by confining our attention to a single example.

We will suppose a farm consisting of one thousand acres, two hundred very good land, three hundred merely tolerable, and the remainder barren down, affording only a scanty sheep-walk. We will suppose the farmer to employ upon it twenty men, and to obtain an average annual product, which, to reduce it to a single denomination, we will call six hundred quarters of wheat. We will suppose him now to double the number of his labourers, and we shall see what probability there is that the produce will consequently be doubled. If the twenty additional labourers are employed in cultivating the down land, they must necessarily produce a less return than that which is produced on the other land by the previous twenty, as the land is supposed to be worse. It is equally clear that their labour, if applied to the land already in cultivation, will be less productive than the labour previously applied to it; or, in other words, that the produce of that land, though increased, will not be doubled, since on no other principle can we account for any land except the very best having been ever cultivated. For if the farmer could have gone on applying additional labour to land already in cultivation without any diminution in the proportionate return, it is clear that he never would have cultivated the three hundred acres of inferior land. In fact, if this were the case, if additional labour employed in agriculture gave a proportionate return, he never need have cultivated more than a single acre, or even a single rood. It is probable that in the supposed case he would employ some of his additional labourers in breaking up a portion of the down, and some of them in cultivating more highly the land already in tillage. So employed, they might produce an additional crop of four hundred, or five hundred, or five hundred and fifty quarters, but it is certain that the additional crop would not be equal to the whole six hundred previously obtained: the produce would be increased, but would not be doubled.

This imaginary farm is a miniature of the whole Kingdom. We have in England large tracks of barren waste, and we have under cultivation soil of every description of fertility, from that which produces forty bushels of wheat an acre to that which produces, with the same labour, and on the same extent of land, only twelve or thirteen. If additional produce is to be raised, the resource, generally speaking, must be either the cultivation of what has been as yet untilled on account of its barrenness, or the employment of additional labour on what is now in cultivation. That in either case the additional produce is not likely to be in the proportion of the additional labour is as obvious in the case of the whole Kingdom as it has appeared to be in that of a single farm.

But the proposition which we have been endeavouring to illustrate, though general, is not universal; it is subject to material exceptions. In the first place, the negligence or ignorance of the occupier, or proprietor, or obstacles of ownership, often prevent for a long time particular portions of land from being subjected to the average degree of labour bestowed on land of equal capability. Increased labour, when at length bestowed on land so circumstanced, may fairly be expected to be as productive, indeed more productive, than the average of agricultural labour. Advantages of this kind have sometimes been derived from extensive operations of drainage and embankment; but the chances of great profit are so apt to blind men to the amount of physical obstacles, that projects of this kind are perhaps more frequently attempted prematurely than deferred till after the time when an increased demand for raw produce first rendered them fair speculations. Undertakings which have been postponed in consequence of obstacles arising from ownership are far more frequently productive. The enclosure of a common often subjects to the plough land of which the former unproductiveness was not owing to deficient fertility. Effects similar in kind, though not in degree, often take place when an estate becomes unfettered after the title has been long so circumstanced that the farmers could not rely on the duration or renewal of their leases. In these cases considerable additional produce may often be obtained by a comparatively small addition of labour.

But the most important exception to the general rule takes place when increase of labour is accompanied by increase of skill. More efficient implements, a better rotation of crops, a greater division of labour, in short, improvements in the art of agriculture, generally accompany the increase of agricultural labour. They always accompany that increase when it is accompanied by an increase of the capital as well as of the population of a Country; and they always counteract, and often outweigh, the inferiority or diminished proportional powers of the soil to which they are applied.

The total amount of the annual agricultural produce of Great Britain has much more than doubled during the last hundred years; but it is highly improbable that the amount of labour annually employed in agriculture has also doubled. It is not supposed that during that period the population of Great Britain has more than doubled; and the principal increase has till lately been in the manufacturing districts. The last hundred years, with all their misfortunes, form the most prosperous period of our History. We owe to them the enclosure of millions of acres formerly almost useless common field; we owe to them almost all that we possess that deserves the name of Agricultural Science; and we owe to them also all the canals, and almost all the roads, which, by obviating in a great measure the accidents of situation, enable the amount of labour to bear throughout the Kingdom something like an average proportion to the quality of the soil on which it is employed. It is possible, though certainly not probable, that our progress may be equal during the next hundred years; but though indefinite, it certainly cannot be infinite. It is obviously impossible that the produce of the soil of a given district can increase geometrically for ever, whatever be the amount of the labour employed on it.

On the other hand, every increase in the number of manufacturing labourers is accompanied not merely by a corresponding but by an increased productive power. If three hundred thousand families are now employed in Great Britain to manufacture and transport two hundred and forty millions of pounds of cotton, it is absolutely certain that six hundred thousand families could manu-

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facture and transport four hundred and eighty millions of pounds of cotton. It is, in fact, certain that they could do much more. It is not improbable that they could manufacture and transport seven hundred and twenty millions. The only check by which we can predict that the progress of our manufactures will in time be retarded, is the increasing difficulty of importing materials and food. If the importation of raw produce could keep pace with the power of working it up, there would be no limit to the increase of wealth and population.

Distribution.

Distribution.

Of the three great branches of Political Economy, the nature, the production, and the distribution of wealth, we have now considered the two former, and we proceed to treat of the last, namely, of the laws according to which all that is produced is *distributed* among those who become its ultimate consumers. In that state of society which is presupposed by the Political Economist, this is principally effected by means of exchange. We may indeed conceive a state of human existence admitting of this distribution without the intervention of exchanges. But such a situation of society, if it can be called society, neither deserves nor requires scientific investigation. Political Economy considers men in that more advanced state, which may fairly be called their natural state, since it is the state to which they are impelled by the provisions of nature, in which each individual relies on his fellows for the greater part, in many cases for the whole of what he consumes, and supplies his own wants principally or wholly by the exchanges in which he contributes to theirs.

But we must admit that we use each of the words production and exchange in a sense rather more extensive than is usual. We have already stated that we apply the word production to much that would commonly be called appropriation, and that we include under exchanges what are usually termed public burdens. We consider all that is received by the officers of Government as given in exchange for services affording protection, more or less complete, against foreign or domestic violence or fraud. It is true, as we have already remarked, that this exchange is conducted on peculiar principles. In those Governments which are not democratic or representative, the rulers themselves assess the amount which they are to receive, and generally assess it at the utmost which, under such circumstances, can be extorted from their subjects. And even under representative or democratic institutions, no individual inhabitant is permitted to refuse his share of the general contribution, though he should disclaim his share in the general protection. But the transaction, though often involuntary, and still more often inequitable, is still an exchange, and on the whole a beneficial exchange. The worst and most inefficient Government affords to its subjects a cheaper and a more effectual protection than they could obtain by their individual and unaided exertions.

The laws by which exchanges are regulated may be divided into two great branches. The one comprises those laws which apply generally to all exchanges; the other those which apply specifically to the respective kinds of exchanges in which the owners of the different productive instruments exchange specifically with one another the produce of those instruments.

In treating of the one we have to consider the general laws which regulate exchanges; in treating of the other, the relative proportions in which different classes of the community benefit by those laws. The things exchanged will be the principal subjects of the one discussion, the exchanging parties of the other.

Distribution. Nomenclature.

One of the greatest difficulties to which a writer on Political Economy is exposed, arises from the mutual dependence of the different propositions constituting the Science; a dependence which makes it difficult to explain any one without a frequent allusion to many others. And this is particularly the case with respect to distribution. The proportions in which different classes of the community are entitled to the things that are produced cannot be explained without a constant reference to the general laws of exchange; and, on the other hand, those laws cannot be discussed without a constant reference to the exchanging parties. Admitting, as we are forced to do, that no arrangement can be free from objection, we have thought that the least objectionable mode of presenting the subject of distribution will be to begin by a general classification of the parties among whom the results of the different instruments of production are divided; then to proceed to state the general laws of exchange; and, lastly, to point out the general circumstances which decide in what proportions the different classes of the community share in the general distribution.

According to the usual language of Political Economists, labour, capital, and land are the three instruments of production; labourers, capitalists, and landlords are the three classes of producers; and the whole produce is divided into wages, profit, and rent: the first designating the labourer's share, the second that of the capitalist, and the third that of the landlord. We approve, on the whole, of the principles on which this classification is founded, but we have been forced, much against our will, to make considerable alterations in the language in which it has been usually expressed; to add some new terms, and to enlarge and contract the signification of some others.

It appears to us that, to have a nomenclature which should fully and precisely indicate the facts of the case, not less than *twelve* distinct terms would be necessary. For each class there ought to be a name for the *instrument* employed or exercised, a name for the *class of persons* who employ or exercise it, a name for the *act* of employing or exercising it, and a name for the *share* of the produce by which that act is remunerated. Of these terms we have not much more than half, as will appear if we examine each class separately.

For the first class we have the terms "to labour," "a labourer," and "wages." Neither of these terms expresses the instruments of production: the substantive "labour," and the verb "to labour," express merely an act. "A labourer" is an agent, and wages are a result: but what is the thing employed? what is it that the labourer exerts? Clearly his mental or bodily faculties. With the addition of this term the nomenclature of the first class will be complete. To labour is to employ strength of body or mind for the purpose of production; the person who does so is a labourer, and wages are his remuneration.

In the second class we have the words capital, capitalist, and profit. These terms express the instrument, the person who employs or exercises it, and his remuneration; but there is no familiar term to express the act, the conduct of which profit is the reward, and which

bears the same relation to profit which labour does to wages. To this conduct we have already given the name of abstinence. The addition of this term will complete the nomenclature of the second class. Capital is an article of wealth, the result of human exertion, employed in the production or distribution of wealth. Abstinence expresses both the act of abstaining from the unproductive use of capital, and also the similar conduct of the man who devotes his labour to the production of remote rather than of immediate results. The person who so acts is a capitalist, the reward of his conduct is profit.

The defectiveness of the established nomenclature is more striking when we come to the third class. Wages and profits are the creation of man. They are the recompense for the sacrifice made in the one case, of ease, in the other, of immediate enjoyment. But a considerable part of the produce of every Country is the recompense of no sacrifice whatever; is received by those who neither labour nor put by, but merely hold out their hands to accept the offerings of the rest of the community.

The powers of nature, as distinguished from those of man, are necessary to afford a field for the exercise of human abstinence and labour. Of these, some from their abundance and the notoriety of the means of employing them, are incapable of appropriation. Being universally accessible, they bear no price notwithstanding their utility; and what has been produced with their assistance has no value beyond that of the labour and abstinence which it has cost. It sells therefore for a price equal to, but not exceeding, the sum of the wages and profits which must be paid if the production is to be continued. The agency of nature is equally essential to the production of timber in the forests of Upper Canada and in England. But the supply of timber in the forests of Upper Canada is practically unlimited. No portion of the price of a Canadian hut is paid for the agency of nature in producing the logs of which it is constructed. The pine while standing was valueless. The purchaser pays only for the labour and abstinence necessary to fell and to fashion it.

But the assistance of an *appropriated* natural agent may render possible the production of a commodity more valuable than the result of equal labour and abstinence without such assistance. Such a commodity sells for a price exceeding the sum of the wages and profits which are sufficient to repay the capitalist and the labourer who have been employed on it. The surplus is taken by the proprietor of the natural agent, and is his reward, not for having laboured or abstained, but simply for not having withheld what he was able to withhold; for having permitted the gifts of nature to be accepted.

If we subtract from the price of an English oak what must be paid for the labour of him who planted the sapling, and for the abstinence of those who allowed it to grow for a century, still something is to be paid for the use of the land by which it was nourished. And that is the price of the agency not of man but of nature.

Of the agents afforded by nature, the principal is the land with its rivers, ports, and mines. In the rare cases in which the quantity of useful land is practically unlimited, a state of things which occurs only in the early stages of colonization, land is an agent universally accessible, and, as nothing is paid for its use, the whole produce belongs to the cultivators, and is divided, under the names of wages and profit, between the capitalists and the labourers, of whose abstinence and industry it is the result.

But in all old Countries, and even in colonies within a very few years after their foundation, certain lands, from peculiar advantages of soil or situation, are found to make more than the average return to a given expenditure of capital and industry. The proprietor of such lands, if he cultivate them himself, receives a surplus after having paid the wages of his labourers and deducted the profit to which he is entitled on his capital. He of course receives the same surplus if, instead of cultivating them himself, he lets them out to some other capitalist. The tenant receives the same profit, and the labourers receive the same wages as if they were employed on land possessing merely average natural advantages; the surplus forms the rent of the proprietor, or, as we usually term him, the landlord. The whole produce, instead of two, is divided into three shares—rent, profit, and wages. If the owner is also the capitalist or farmer, he receives two of these shares, both the profit and the rent. If he allow it to be cultivated by the capital of another, he receives only rent. But rent, with or without profit, he necessarily receives. And when the whole of a Country has been appropriated, though it be true, as will be shown hereafter, that some of the produce is raised by the application of additional capital without payment of additional rent, and may therefore be said to be raised rent free, yet it is equally true that a rent is received from every cultivated acre; a rent rising or falling according to the accidents of soil and situation, but the necessary result of limited extent and productive power.

It is obvious, however, as we have already stated, that land, though the principal, is not the only natural agent that can be appropriated. The mere knowledge of the operations of nature, as long as the use of that knowledge can be confined either by secrecy or by law, creates a revenue to its possessor analogous to the rent of land. The knowledge of the effect on the fibres of cotton of rollers moving with different velocities, enabled a village barber to found in a very few years a more than aristocratic fortune. Still greater wealth might probably have been acquired by Dr. Jenner, if he could have borne somewhat to limit the benefits which he has conferred on mankind.

When the author of a useful discovery puts it himself in practice, he is like a proprietor farming his own property; the produce, after paying average wages for the labour, and average profits for the capital, employed, affords a still further revenue, the effect not of that capital or of that labour, but of the discovery, the creation not of man but of nature. If, instead of using it himself, he let out to another the privilege of using it, he obtains a revenue so precisely resembling the rent of land that it often receives the same name. The payment made by a manufacturer to a patentee for the privilege of using the patent process is usually termed in commercial language a *rent*; and under the same head must be ranked all the peculiar advantages of situation or connection, and all extraordinary qualities of body and mind. The surplus revenue which they occasion beyond average wages and profits is a revenue for which no additional sacrifice has been made. The proprietor of these advantages differs from a landlord only in the circumstance that he cannot in general let them out to be used by another, and must consequently either allow them to be

useless or turn them to account himself. He is forced, therefore, always to employ on them his own industry, and generally his own capital, and receives not only rent but wages and profit. If, therefore, the established division is adhered to, and all that is produced is to be divided into rent, profit, and wages,—and certainly that appears to be the most convenient classification;—and if wages and profit are to be considered as the rewards of peculiar sacrifices, the former the remuneration for labour, and the latter for abstinence from immediate enjoyment, it is clear that under the term "rent" must be included all that is obtained without any sacrifice; or, which is the same thing, beyond the remuneration for that sacrifice; all that nature or fortune bestows either without any exertion on the part of the recipient, or in addition to the average remuneration for the exercise of industry or the employment of capital.

But though we see no objection to this extension of the word rent, the terms land and landlord are too precise to admit of being equally extended. It would be too great an innovation to include under the term land every natural agent which is capable of appropriation, or under the term landlord every proprietor of such an agent. For these terms we must substitute those of *natural agent*, and *proprietor of a natural agent*. And the third class will then have a term for the third instrument of production, a term for the owner of that instrument, and a term for the share which he receives of the produce: terms corresponding with the terms faculties of body and mind, labourer, and wages, as applied to the first class, and with capital, capitalist, and profit, as applied to the second. We shall still want a term corresponding with labour and abstinence,—a term indicating the *conduct* which enables the proprietor of a natural agent to receive a rent. But as this conduct implies no sacrifice,—as it consists merely in not suffering the instrument of which he is the owner to be useless, it perhaps does not require a distinct designation. When a man possesses an estate, we take it for granted that he does not allow it to lie waste, but either uses it himself, or lets it to a tenant. In ordinary language the receipt of rent is included under the term ownership. There will therefore be little danger of obscurity if we consider the word "possess," when applied to the proprietor of a natural agent, as implying the receipt of the advantages afforded by that agent, or, in other words, of rent. Talents, indeed, often lie idle, but in that case they may be considered for economical purposes as not possessed. In fact, unaccompanied by the will to use them, they are useless.

But though the whole produce may be considered as divided into three shares, one of which is taken by the capitalists, another by the labourers, and another by the proprietors of the natural agents which have concurred in the production, it is very seldom that any given commodity, or the produce of any one productive exertion, is thus actually divided. The nearest approach to it takes place in those cases in which producers belonging to different classes become partners and agree that the produce of their joint exertions shall be sold and the price divided between them. Such a partnership is often formed between a capitalist and his labourers when the success of the enterprise depends much on the zeal of the labourers, and the capitalist is unable to overlook them. Such is the case in the Greenland fishery. The men seldom receive preascertained wages, but, on the termination of the voyage, the blubber is sold, and the price divided between the owners and the crew. The practice is the same in privateering, and probably in many other maritime speculations. Somewhat similar is the mode of letting land called the métayer system. Under that system, which is still common in the Continent of Europe, and probably is always to be found in a certain state of society, the landlord supplies the capital as well as the land, and receives half the crop, the remainder forming the wages of the tenant or head-labourer, and of the inferior work-people in his employ. But these are exceptions occasioned by the peculiarities of the adventure, or by the poverty or ignorance of imperfect civilization. The usual practice is to consider one of the parties as entitled to the whole product, paying to the others a price for their co-operation. The person so entitled is uniformly the capitalist: the sums which he pays for wages and rent are the purchase-money for the services of the labourer, and for the use of the natural agent employed.

In most cases a considerable interval elapses between the period at which the natural agent and the labourer are first employed, and the completion of the product. In this climate the harvest is seldom reaped until nearly a year after it has been sown; a still longer time is required for the maturity of oxen; and a longer still for that of a horse; and sixty or seventy years may pass between the commencement of a plantation, and the time at which the timber is saleable. It is obvious that neither the landlord nor the labourer, as such, can wait during all this interval for their remuneration. The doing so would, in fact, be an act of abstinence. It would be the employment of land and labour in order to obtain remote results. This sacrifice is made by the capitalist, and he is repaid for it by his appropriate remuneration, profit. He advances to the landlord and the labourer, and in most cases to some previous capitalist, the price of their respective assistance; or, in other words, the hire of the land and capital belonging to one, and of the mental and bodily powers of another, and becomes solely entitled to the whole of the product. The success of his operations depends on the proportion which the value of that produce, (or, in commercial language, the value of his returns) bears to the value of his advances, taking into consideration the time for which those advances have been made. If the value of the return is inferior to that of the advance, he is obviously a loser; he is a loser if it be merely equal, as he has incurred abstinence without profit, or, in ordinary language, has lost the interest on his capital. He is a loser even if the value of his returns do not exceed that of his advances by an amount equal to the current rate of profit for the period during which the advance has been made. In any of these cases the product is sold, so far as the capitalist is concerned, for less than the cost of its production. The employment of capital, therefore, is necessarily a speculation; it is the purchase of so much productive power which may or may not occasion a remunerative return.

The common language of Economists, therefore, which describes the landlord, the capitalist, and the labourer as sharers of the produce, is a fiction. Almost all that is produced is in the first instance the property of the capitalist; he has purchased it by having previously paid the rent and wages, and incurred or paid for the abstinence, which were necessary to its production. A portion of it, but generally a small portion, he consumes himself in the state in which he receives it; the re-

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mainder he sells. He may, if he think fit, employ the price of all that he sells in purchases for his own gratification; but he cannot remain a capitalist unless he consent to employ some portion of it in the hire of the land and labour, by the assistance of which the process of production is to be continued or recommenced. He cannot, generally speaking, fully retain his situation as a capitalist unless he employ enough to hire as much land and labour as before; and if he wish to raise himself in the world, he must, generally speaking, not merely keep up but increase the sum which he devotes to the purchase of productive force. If, for instance, he has hired the use of a farm for a year for £1000, and has paid £2000 more as wages to his labourers, and has expended £1000 in the purchase, from other capitalists, of agricultural stock, and at the end of the year has sold the produce for £4400, he may, if he like, spend on his own gratification the whole of that £4400; or he may so spend only £400, and employ the rest in hiring the farm and the labourers, and purchasing stock for another year; or he may spend on himself only £200, and by employing productively £4200 instead of £4000, hire more land, or more labourers, or purchase more stock and provide for the increase of his capital and his profit. But in whatever way he employ his £4400, he still must pay it to landlords, (using that word to comprise all proprietors of natural agents,) capitalists, and labourers.

It has been objected, however, that this nomenclature is incomplete. Rent, profit, and wages, it has been said, designate only those portions of the annual produce which the producers consume for their own gratification. They form the *revenue* of a nation. A further portion, and a very large one, must be employed not as revenue, but as capital; not in directly supplying the wants or directly ministering to the enjoyments of either landlords, labourers, or capitalists, but merely in keeping up the instruments of production. Thus of the farmer's whole return, which we have supposed to be of the value of £4400, we may suppose a portion, amounting in value to £200, to have consisted of corn which he returned to the earth as seed, and another portion, amounting to the same value, to have consisted of the forage which he gave to his working cattle. It has been said that neither this seed nor this forage was rent, profit, or wages.

The answer to this objection is, that the seed-corn and forage in question were the result of land, labour, and abstinence; they were entitled, therefore, when produced, to be denominated rent, wages, or profit, and the circumstance that they were employed to produce future instead of immediate gratification does not vary their character. When produced, they were revenue: their *conversion* into capital was a subsequent accident. No one would except against the expression that such and such a labourer has *saved part of his wages* and employed them in stocking his garden. If the words revenue and income were co-extensive with expenditure, the common statement, that a man is living within his income, would be a contradiction in terms.

Perhaps this may be made clearer if we retrace the history of capital.

The primary instruments of production were labour, and those productive agents which are spontaneously afforded by nature. The first dwellers on the earth had only rent and wages. The savage who, instead of devouring the animals which he had entrapped, reserved them to become the origin of a domesticated flock, and he who reserved, to be employed as seed, some of the grains which he had gathered, laid the foundation of capital. The produce of that flock and of that seed was partly rent, partly wages, and partly profit. And it did not cease to be so, although he refused to employ the whole of it on his immediate gratification.

It must be admitted, however, that the portion of the annual produce which is employed in the production or the support of brute or inanimate capital is not usually termed rent, wages, or profit. It has not, in fact, any specific name. But it appears to us to be the most philosophical arrangement to consider it as rent, wages, or profit, according to the character of its proprietor, without regard to its subsequent destination.

Exchange.

Having made this general classification of the parties among whom the results of the different productive instruments are divided, we now proceed to consider the general laws which regulate the proportions in which those results are exchanged for one another. To a certain degree this question was considered when we treated of value; but not having at that time explained the words production, wages, profit, or rent, we were unable to do more than to state and illustrate the following propositions:—

First, that all those things, and those things only, are susceptible of exchange, which, being transferable, are limited in supply, and are capable, directly or indirectly, of affording pleasure or preventing pain; a capacity to which we have affixed the name of utility. Secondly, that the reciprocal values of any two things, or, in other words, the quantity of the one which will exchange for a given quantity of the other, depend on two sets of causes; those which occasion the utility and limit the supply of the one, and those which limit the supply and occasion the utility of the other. The causes which occasion the utility and limit the supply of any given commodity or service, we denominated the *intrinsic* causes of its value. Those which limit the supply and occasion the utility of the commodities or services for which it is capable of being exchanged, we denominated the *extrinsic* causes of its value. And, thirdly, that comparative limitation of supply, or, to speak more familiarly, though less philosophically, comparative scarcity, though not sufficient to constitute value, is by far its most important element; utility, or, in other words, demand, being mainly dependent on it. We had not then shown the means by which supply is effected. Having done this, having shown that human Labour and Abstinence, and the spontaneous agency of Nature, are the three instruments of production, we are at liberty to explain what are the obstacles which limit the supply of all that is produced, and the mode in which those obstacles affect the reciprocal values of the different subjects of exchange.

In the following discussion, however, we shall in general substitute *price* or value in money for general value.

Price.

The general value of any commodity, that is, the quantity of all the other subjects of exchange which might be obtained in return for a given quantity of it, is incapable of being ascertained. Its specific value in any other commodity may be ascertained by the experiment of an exchange; the anxiety of each party in the exchange to give as little, and obtain as much as possible, leading him to investigate, as accurately as he can, the intrinsic causes giving value to each of the articles

to be exchanged. This is, however, a troublesome operation, and many expedients are used to diminish its frequency. The most obvious one is to consider a single exchange, or the mean of a few exchanges, as a model for subsequent exchanges of a similar nature. By an extension of this expedient it may become a model for exchanges not of a similar nature. If given quantities of two different articles are each found by experience to exchange for a given quantity of a third article, the proportionate value of the two first-mentioned articles may, of course, be inferred. It is *measured* by the third. Hence arise the advantages of selecting, as one of the subjects of every exchange, a single commodity, or, more correctly, a species of commodities constituted of individuals of precisely similar qualities. In the first place, all persons can ascertain, with tolerable accuracy, the intrinsic causes which give value to the selected commodity, so that one half the trouble of an exchange is ready performed. And, secondly, if an exchange is to be effected between any other two commodities, the quantity of each that is usually exchanged for a given quantity of the third commodity is ascertained, and their relative value is inferred. The commodity thus selected as the general instrument of exchange, whatever be its substance, whether salt, as in Abyssinia, cowries, on the Coast of Guinea, or the precious metals, as in Europe, is *money*. When the use of such a commodity, or, in other words, of money, has become established, value in money, or *price*, is the only value familiarly contemplated. The scarcity and durability of gold and silver (the substances used as money by all civilized nations) make them peculiarly unsusceptible of alteration in value from intrinsic causes. On these accounts we think it better, in the following discussion, to refer rather to *price* than to general value, and to consider the value of money, so far as it depends on intrinsic causes, to be unvarying.

We must preface our explanation of the effect on price of the causes limiting supply, by a remark which may appear self-evident, but which must always be kept in recollection, namely, that *where the only natural agents employed are those which are universally accessible, and therefore are practically unlimited in supply, the utility of the produce, or, in other words, its power, directly or indirectly, of producing gratification, or preventing pain, must be in proportion to the sacrifices made to produce it, unless the producer has misapplied his exertions; since no man would willingly employ a given amount of labour or abstinence in producing one commodity, if he could obtain more gratification by devoting them to the production of another.*

We now revert to the causes which limit supply.

There are some commodities the results of agents no longer in existence, or acting at remote and uncertain periods, the supply of which cannot be increased, or cannot be reckoned upon. Antiques and relics belong to the first class, and all the very rare productions of Nature or Art, such as diamonds of extraordinary size, or pictures, or statues of extraordinary beauty, to the second. The values of such commodities are subject to no definite rules, and depend altogether on the wealth and taste of the community. In common language, they are said to bear a fancy price, that is, a price depending principally on the caprice or fashion of the day. The Boccaccio, which a few years ago sold for £2000, and after a year or two's interval for £700, may perhaps, fifty years hence, be purchased for a shilling. Relics which, in the IXth Century, were thought too valuable to admit of a definite price, would now be thought equally incapable of price in consequence of their utter worthlessness. In the following discussion we shall altogether omit such commodities, and confine our attention to those of which the supply is capable of increase, either regular, or sufficiently approaching to regularity, to admit of calculation.

The obstacle to the supply of those commodities which are produced by labour and abstinence, with that assistance only from nature which every one can command, consists solely in the difficulty of finding persons ready to submit to the labour and abstinence necessary to their production. In other words, their supply is limited by the cost of their production.

Cost of production.

The term "cost of production" must be familiar to those who are acquainted with the writings of modern Economists; but, like most terms in Political Economy, though currently used, it has never been accurately defined; and it appears to us impossible that it should have been defined without the assistance of the term "abstinence," or of some equivalent expression.

Mr. Ricardo, who originally introduced the term "cost of production," uses as an equivalent expression, "the quantity of labour which has been bestowed on the production of a commodity." Mr. Mill, ch. iii. sec. 2. appears to consider cost of production as equivalent to "quantity of labour." Mr. Malthus more elaborately defines it as "the advance of the quantity of accumulated and immediate labour necessary to production, with such a per centage upon the whole of the advances for the time they have been employed as is equivalent to ordinary profits." *Definitions*, p. 242.

In a note to the third edition, page 46, Mr. Ricardo admits that profit also forms a part of the cost of production. Mr. Mill, by a stretch of language, in the convenience of which we cannot concur, includes profit under the term labour. The definitions of Mr. Ricardo and Mr. Mill appear, therefore, to coincide. And that adopted by Mr. Malthus only differs from them in referring, not to the labour that *has* been employed, but to that which must be employed if the production must be continued. In this respect the language of Mr. Malthus is undoubtedly the most correct. The sacrifices that *have* been made to produce a given commodity have no effect on its value. All that the purchaser considers is the amount of sacrifice that its production would require at the time of the exchange. If the expense of producing a pair of stockings were suddenly to fall or to rise by one half, a rise or fall in the value of the existing stockings would be the consequence, although the labour that *has* been employed on them is of course unalterable. And when Mr. Ricardo and Mr. Mill speak of the labour which *has* been employed on a commodity as affecting its value, they must be understood as implying that the circumstances of production remain unchanged.

Colonel Torrens considers cost of production as equivalent to "the amount of capital expended on production," and refuses to consider profit as forming one of its elements. His remarks throw so much light on the whole subject, that we will venture to extract them at some length.

"Those writers who contend for the general equality of market and natural price, include the customary rate of profit under the term natural price, or cost of production. But this classification is highly unphilosophi-

cal and incorrect. The profits of stock never make any part of the expense of production; they are, on the contrary, a new creation brought into existence in consequence of this expense. The farmer, we will suppose, expends one hundred quarters of corn in cultivating his fields, and obtains in return one hundred and twenty quarters. In this case twenty quarters, being the excess of produce above expenditure, constitute the farmer's profit, but it would be absurd to call this excess or profit a part of the expenditure. The expenditure or cost of production was one hundred quarters. It has been now repaid with a surplus of twenty quarters; and, unless the surplus which remains after the expenditure is replaced be a part of the expenditure, unless, in fact, one hundred and twenty quarters be equal to a hundred, it is impossible that market price should be equivalent to natural. Supposing that corn is £3 per quarter, then, in the case we have stated, the natural price of the farmer's produce, or the one hundred quarters expended upon production, will be equivalent to £300; while the produce of one hundred and twenty quarters obtained in return will be equivalent to £360. The excess of market above natural price, or cost of production, is profit; and to contend that this profit is included in the cost of production, is the same thing as contending that the hundred quarters, or £300 laid out in cultivation, are equal to the one hundred and twenty quarters, or £360 thereby obtained.

"In manufacturing, as well as in agricultural industry, the profit of stock is distinct from the cost of production. The master manufacturer expends a certain quantity of raw material, of tools and implements of trade, and of subsistence for labourers, and obtains in return a given quantity of finished work. This finished work must possess a higher exchangeable value than the materials, tools, and subsistence, by the advance of which it was obtained; otherwise the master could have no inducement to continue his business. Manufacturing industry would cease, if the value produced did not exceed the value expended. But it is the excess of value which the finished work possesses above the value of the materials, implements, and subsistence expended, that constitutes the master's profit; and therefore we cannot assert that the profit of his stock is included in the cost of production without affirming the gross absurdity, that the excess of value above expenditure constitutes a part of expenditure. Supposing that the materials, tools, and subsistence cost £300, and that the finished work is worth £360, then the difference will be the master's profit; and we cannot maintain that the annual profit is included in the amount of expenditure, or cost of production, without urging the contradiction that £300 are equal to £360.

"The profit of stock, so far from forming any part of the cost of production, is a surplus remaining after this cost has been completely replaced. In carrying on their business, the farmer and manufacturer do not expend their profit, they create it. It forms no part of their first advances; on the contrary, it forms a part of their subsequent returns. It could not have been employed in carrying on the work of production, because, until this work was completed, it had no existence. It is essentially a surplus, a new creation, over and above all that is necessary to replace the cost of production, or, in other words, the capital advanced. It is hoped that enough has been said to convince the reader of the nature of the error into which those Economists fall who maintain that the profit of stock is included in the expense of production, and that natural and market price tend to an equality. Market price is that which we give in order to obtain a commodity by exchange in the market: natural price is that which we give to effect a purchase at the great storehouse of nature: it consists of the several articles of capital employed in production, and cannot by possibility include the surplus or profit created during the progress of production."*

Colonel Torrens's remarks are just, so far as they apply to the mere expressions which he is criticising. Profit is certainly not a means, but a result. It is true that unless that result were expected, production would not be continued. Neither the farmer nor the manufacturer could be induced by any other motive to abstain from the unproductive enjoyment of his capital; so food would not be produced unless its consumption were necessary or agreeable. But the obtaining a profit is no more a part of the cost of producing a harvest than the gratification of appetite is a part of the cost of producing a dinner, or protection from cold part of the cost of producing a coat.

Want of the term abstinence, or of some equivalent expression, has led Mr. Malthus into inaccuracy of language. He seems to have felt that something besides mere labour is essential to production. He felt that simple industry would not convert a naked heath into a valuable wood; that the planter, in addition to the labour of inserting and protecting the saplings, incurred the additional *sacrifice* of directing his labour to the production of remote results; and that the successive generations of proprietors, in suffering the young plantation to become mature, sacrificed their own emolument to that of their successors. He seems to have felt that these sacrifices were part of the cost of producing the wood, and, having no term to express them, he denominated them by the name of their reward. When he termed profit a part of the cost of production, he appears to us to have meant not profit, but that conduct which is repaid by profit: an inaccuracy precisely similar to that committed by those who term wages a part of the cost of production; meaning not wages, which are a result, but the labour for which wages are the remuneration.

Colonel Torrens's error is an error of omission. He refuses to consider profit as part of the cost of production, but he does not substitute for it abstinence or any equivalent expression. Although he admits that where equal capitals are employed the value of the products may differ if the one be brought to market sooner than the other, he has not stated the principle on which this difference depends. That principle is that, though in both cases the labour employed is the same, more abstinence is necessary in the one case than in the other.

By *cost of production*, then, we mean the sum of the labour and abstinence necessary to production. But cost of production, thus defined, must be divided into the cost of production on the part of the producer or seller, and the cost of production on the part of the consumer or purchaser. The first is of course the amount of the labour and abstinence which must be undergone by him who offers for sale a given class of commodities

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* Torrens, *On the Production of Wealth*, 51—55.

or services in order to enable him to continue to produce them. The second is, the amount of the labour and abstinence which must be undergone by those to whom a given commodity or service is offered for sale, if, instead of purchasing, they themselves, or some of them on the behalf of themselves and the others, were to produce it. The first is equal to the minimum, the second to the maximum of price. For, on the one hand, no man would continue to produce, for the purpose of sale, what should sell for less than it cost him to produce it. And, on the other hand, no men would continue to buy what they themselves, or some of them on the behalf of themselves and the others, could produce at less expense. With respect to those commodities, or, to speak more accurately, with respect to the value of those parts or attributes of commodities, which are the subjects of equal competition, which may be produced by all persons with equal advantages, the cost of production to the producer and the cost of production to the consumer are the same. Their price, therefore, represents the aggregate amount of the labour and abstinence necessary to continue their production. If their price should fall lower, the wages or the profits of those employed in their production must fall below the average remuneration of the labour and abstinence that must be undergone if their production is to be continued. In time, therefore, it is discontinued or diminished, until the value of the product has been raised by the diminution of the supply. If the price should rise beyond the cost of their production, the producers must receive more than an average remuneration for their sacrifices. As soon as this has been discovered, capital and industry flow towards the employment which, by this supposition, offers extraordinary advantages. Those who formerly were purchasers, or persons on their behalf, turn producers themselves, until the increased supply has equalized the price with the cost of production.

Some years ago London depended for water on the New River Company. As the quantity which they can supply is limited, the price rose with the extension of buildings, until it so far exceeded the cost of production as to induce some of the consumers to become producers. Three new Water Companies were established, and the price fell as the supply increased, until the shares in the New River Company fell to nearly one-fourth of their former value; from £15,000 to £4000. If the metropolis should continue to increase these transactions will recur. The price of water will increase and exceed the cost at which it could be afforded. New Companies will arise, and, unless the additional supply is checked by greater natural obstacles than those which the existing Companies have to surmount, the price will again fall to its present level.

But though, under free competition, cost of production is the regulator of price, its influence is subject to much occasional interruption. Its operation can be supposed to be perfect only if we suppose that there are no disturbing causes, that capital and labour can be at once transferred, and without loss, from one employment to another, and that every producer has full information of the profit to be derived from every mode of production. But it is obvious that these suppositions have no resemblance to the truth. A large portion of the capital essential to production consists of buildings, machinery, and other implements, the results of much time and labour, and of little service for any except their existing purposes. A still larger portion consists of knowledge and of intellectual and bodily dexterity, applicable only to the processes in which those qualities were originally acquired. Again, the advantage derived from any given business depends so much upon the dexterity and the good fortune with which it is managed, that few capitalists can estimate, except upon an average of some years, the amount of their own profits, and still fewer can estimate those of their neighbours. Established businesses, therefore, may survive the causes in which they originated, and become gradually extinguished as their comparative unprofitableness is discovered, and the labourers and capital engaged in them wear away without being replaced; and, on the other hand, other employments are inadequately supplied with the capital and industry which they could profitably absorb. During the interval, the products of the one sell for more, and those of the others for less, than their cost of production. Political Economy does not deal with particular facts but with general tendencies, and when we assign to cost of production the power of regulating price in cases of equal competition, we mean to describe it not as a point to which price is attached, but as a centre of oscillation which it is always endeavouring to approach.

We have seen that, under circumstances of equal competition, or, in other words, where all persons can become producers, and that with equal advantages, the cost of production on the part of the producer or seller, and the cost of production on the part of the consumer or purchaser, are the same, and that the commodity thus produced sells for its cost of production; or, in other words, at a price equal to the sum of the labour and abstinence which its production requires; or, to use a more familiar expression, at a price equal to the amount of the wages and profits which must be paid to induce the producers to continue their exertions. It has lately been a general opinion that the bulk of commodities is produced under circumstances of equal competition. "By far the greater part of those goods," says Mr. Ricardo, (*Principles*, &c. p. 3.) "which are the objects of desire are produced by labour, and may be multiplied almost without any assignable limit if we are disposed to bestow the labour necessary to obtain them. In speaking then of commodities, of their exchangeable value, and of the laws which regulate their relative prices, we always mean such commodities only as can be increased in quantity by the exertion of human industry, and in the production of which competition operates without restraint."

Now it is clear that the production in which no appropriated natural agent has concurred, is the only production which has been made under circumstances of perfectly equal competition. And how few are the commodities of which the production has in no stage been assisted by peculiar advantages of soil, or situation, or by extraordinary talent of body or mind, or by processes generally unknown, or protected by law from imitation. Where the assistance of these agents, to which we have given the general name of natural agents, has been obtained, the result is more valuable than the result of equal labour and abstinence unassisted by similar aids. A commodity thus produced is called the subject of a *monopoly*; and the person who has appropriated such a natural agent, a *monopolist*.

Monopolies.

Monopolies may be divided into four kinds.

1. Where the monopolist has not the exclusive power of producing, but only certain exclusive facilities as a producer, and can increase, with undiminished, or even increased facility, the amount of his produce.

The value of a commodity produced under such cir-

cumstances approaches more nearly to the cost of production on the part of the seller, than that of any other monopolized commodity. It is obvious that its price can never permanently fall below the value of the sacrifices which must be made by the producer, and, on the other hand, that it never can permanently rise above the value of the sacrifices which must be made by the consumers, if, instead of purchasing, they, or some persons in their behalf, were to turn producers. Sir R. Arkwright's yarn could not sell for more than yarn of an equal quality produced without the aid of his patent machinery; nor would Arkwright have sold it for less than the value of the labour and abstinence employed in its production. The first was the cost of production to the consumer, the second the cost of production to the producer. But the difference between the two was enormous; the cost to Arkwright was not one-fifth of what it would have been to his customers.

His inventions enabled him to produce a greater quantity, but not a better quality. The finger and thumb constitute an instrument more delicate than any system of rollers, and the muslin formed by the comparatively unassisted labour of the Hindoo is finer and more durable than the produce of our elaborate manufactories. The price which Arkwright *could* exact was therefore limited, as we have seen, by the competition of other productive instruments, more expensive but quite as efficient. The price which he *did* exact was still further limited by a regard to his own interest. He had discovered an instrument of which the powers, instead of being exhausted, increased with every increase in its application. To erect a mill for the purpose of spinning annually a hundred or a thousand pounds of cotton would be madness. The expense of spinning ten thousand pounds very little exceeds the expense of spinning one thousand, and forty thousand might probably be spun at less than double the expense of ten thousand. As the quantity produced is increased, the relative cost of production is diminished. If, therefore, on the sale of ten thousand pounds weight of yarn at a given price, which we will call £10,000, his profit amounted to £5000, the profit of selling one hundred thousand weight at the same price might have amounted to £90,000, and his profit on selling one million pounds weight to £900,000. But to effect this was obviously impossible. As value depends mainly on limitation of supply, he could not have at once offered a large quantity for sale without diminishing the price, if he left that price to be fixed by the competition of the purchasers, or without having a large portion unsold, if he refused to submit to that diminution. His only mode of stimulating a constant increase of consumption was to submit to such a constant lowering of price as should constantly widen the circle of those able and willing to purchase. As is usually the case, his own interest and that of the public coincided, and led him to accept a price far exceeding indeed the cost of production to himself, but falling short by a still wider interval of what would have been the cost of production to them.

Sir R. Arkwright's monopoly, therefore, was of the most limited kind. His remuneration was bounded, and it was not his interest even to approach that boundary.

2. A second kind of monopoly is in the opposite extreme. It exists where price is checked neither by the hopes nor by the fears of the producer, where no competition is dreaded, and no increased supply can be effected. The owners of some vineyards have such a monopoly. Constantia owes its peculiar flavour to the agency of a few acres of ground, and that flavour would be destroyed if high cultivation were employed to force from that ground a larger quantity of wine. As no person but the proprietor of the Constantia farm can be a producer, the price is not checked by any cost of production to the consumer. It is not checked by any wish of the proprietor to increase the consumption, since the quantity produced, and consequently the quantity consumed, is incapable of increase. The price cannot of course fall below the cost of production, but may indefinitely exceed it. It is limited solely by the will and the ability of the consumers. And if fashion were to make it an object of intense desire among the opulent, a pipe of Constantia, produced perhaps at the expense of £20, might sell for £20,000.

3 A third and more frequent kind of monopoly lies between these two extremes, and is neither so strict as the last, nor so comparatively open as the first. This comprises those cases in which the monopolist is the only producer, but, by the application of additional labour and abstinence, can indefinitely increase his production. The book trade affords an illustration. While a work is protected by copyright, no person but the proprietor of that copyright can produce copies: and he may multiply them indefinitely by the application of additional labour and abstinence. There is here no cost of production on the part of the purchaser, and, as far as he is concerned, the price is limited only by his will and ability. The efficient check arises from the interest of the publisher. As is the case with manufactures generally, the relative expense of publication diminishes as the number of copies published increases. It is his interest, therefore, to encourage a large sale by affixing a price but slightly exceeding the cost of production, diminished as that cost is by the magnitude of the produce. A hundred copies of *Waverly* might perhaps, have been sold at ten guineas a copy; but there can be no doubt that a larger aggregate profit was obtained by selling ten thousand at a guinea and a half.

4. The fourth and last class of monopolies exists where production must be assisted by natural agents, limited in number, and varying in power, and repaying with less and less relative assistance every increase in the amount of the labour and abstinence bestowed on them. It is under these circumstances that the greater part of the raw produce, whatever it be, which is the staple food of the inhabitants in every Country, potatoes in Ireland, wheat in England, or rice in India, is produced. It is, in fact, the great monopoly of land; and as there are scarcely any commodities of which the supply is not in some measure limited by the limited extent of the land essential or serviceable to some process in their production, all general theories as to value must be subject to error until the general laws regulating the value of the assistance to be derived from land have been ascertained. It will be necessary, therefore, to examine them at some length.

Land.

The soil of every extensive district is of different degrees of fertility and convenience of situation, and the soils of each degree constitute a distinct class of natural agents, affording each a distinct amount of assistance to the cultivator. And we have seen that each portion of soil, whatever be its fertility, agricultural skill remaining the same, generally gives a less and less proportionate return to each additional quantity of labour and abstinence bestowed on its cultivation, and may be

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Distribution.

Monopoly.

said, therefore, to comprise within itself a system of natural agents of different powers. The different classes of natural agents will be successively employed, in proportion to their efficiency; an inferior class being never resorted to while a superior one is equally accessible: and each class, until it has been completely appropriated, may be considered as practically unlimited in supply, since it is universally accessible. What shall be the worst natural agent employed, or, in other words, to what extent inferior soils shall be cultivated, or additional labour and abstinence employed at a comparative disadvantage on the cultivation of those which are more fertile or better situated, must always be determined by the wealth and wants of the community; by the quantity of agricultural produce which they have the power and the desire to purchase. While those wants can be satisfied by slightly cultivating only a portion of the most fertile and best situated land, that land, though highly productive, indeed more productive in proportion to the labour and abstinence bestowed on it than at any subsequent stage, cannot be a separate and independent source of value. It is then a natural agent universally accessible and its produce, however large, will exchange only for the value of the labour and abstinence employed on its production. In short, the cost of production to the producer, and the cost of production to the consumer, are, under such circumstances, the same. Such is the state of some of the fertile and thinly peopled districts of the tropes. The inhabitants of the greater part of the Tierra Caliente of Mexico appropriate at will from the fertile wilderness over which they are scattered the small patches which afford them the materials of lodging, food, and raiment. We are told that in these districts the labour of a week will provide subsistence for a year, but even this vast productive power, or even any conceivable increase in it, is incapable of giving value to the assistance afforded as long as the supply of that assistance remains unlimited.

It becomes limited, however, in the very earliest stages of improvement. Both the causes and the consequences of this event may be illustrated by tracing the progress of a colony.

When a body of emigrants arrives on the coast of an unoccupied district, their first operation must be to fix the situation of their future metropolis; the seat of government, of law, of foreign trade, and of those manufactures which require the congregation of numerous workmen. We may suppose their numbers and the local advantages to be such as to enable them to occupy, within such a distance from their infant town as to render the expense of carriage immaterial, as much land of the highest fertility as each agricultural family may wish to cultivate. The agricultural produce thus obtained must sell for its cost of production to the producer; every consumer being able at will to turn a producer, with advantages equal to those enjoyed by the existing producers, and being unwilling to give for the result of a given amount of labour and abstinence on their part more than the result of an equal amount of labour and abstinence on his own part. Such a community rapidly increases in numbers and in wealth, and that increase is accompanied by an increased desire and ability to purchase agricultural produce. Until the supply of raw produce has been increased, the price must now rise above the cost of production. But when the most fertile lands within a given distance of the town have been occupied, there remain only three modes of increasing the supply: either 1. by cultivating the fertile lands at a greater distance from the town; or, 2. by cultivating the inferior land in its neighbourhood; or, 3. by employing additional labour and abstinence in the cultivation of the lands already occupied. Whichever of these plans be adopted, and probably they will all be adopted, the additional quantity must be supplied at an increased expense. The first is loaded with the expenses of carriage; and we know that a given amount of labour and abstinence is employed to comparative disadvantage, when applied either to the cultivation of inferior land, or to the further improvement of the best land.

Distribution.

Price.

Monopoly.

Land.

The immediate consequence of the increase of supply must be a fall of price, but a fall not equal to the previous rise. The additional supply is produced under circumstances of equal competition, every consumer having it in his power to turn producer by occupying the more distant or less fertile territory; it sells, therefore, for the cost of production to the producer. But commodities of precisely the same qualities cannot sell in the same market for different prices. The purchaser of a bushel of wheat does not inquire whether it was grown within a furlong or at ten miles from the place of sale. The produce, therefore, of the fertile lands in the immediate vicinity of the market sells at the same price as that of the distant or inferior land.

That price, as it is equal to the cost of production of what is produced at the greatest expense, must exceed the cost of production of what is produced at the least expense. The proprietor of the most fertile and best situated land has no motive to take less, as he cannot, like the owner of a patent, increase the amount of what he produces and continue to produce at equal advantage; and the purchaser cannot support an offer of less, as he cannot turn producer but by submitting to disadvantages which equalize the current price and the cost of production.

As the colony grows into a people and an empire the same processes are repeated. Every increase of wealth and population raises the price of raw produce. Increase of price occasions an increase of supply, raised at a comparatively greater expense. The price falls in consequence of the increased supply, but is prevented from falling to its former level by the increase which has taken place in the cost of producing that part of the whole supply which is brought to market at the greatest expense.

The effect will be the same whether we select for the scene a continent or an island; a district containing soils of every degree of fertility, or of precisely uniform quality. The Anglo-Americans have supplied their constantly increasing wants chiefly by spreading themselves backwards over their unbounded Western territory, and have made little use of inferior soils, or of high cultivation, except in the immediate vicinity of their cities. In Malta, a single acre receives more labour than would be devoted to a square mile in the Illinois; but precisely the same motives impel the Maltese to terrace his mountains into gardens, and the American to reclaim the prairies of the Missouri.

It may be inferred, from the picture which we have given of the progress of society, that we believe an increased difficulty of obtaining raw produce to be the natural incident to an increase of population. In the absence of counteracting causes it certainly would be so; but those causes are so powerful, that, unless checked by legislation, they in many respects balance the causes

Distribution. Price. Monopoly. Land.

which we have been considering. In a colony, the counteracting causes appear likely to preponderate for a period, the duration of which must of course depend in part on the quantity of fertile and unoccupied land in its vicinity. As the circle of appropriated land expands, and the expense of bringing food to the consumers becomes more oppressive, there is a tendency in the consumers to follow the food. The colonial capital, now turned into a metropolis, may continue to send out portion after portion of her increased inhabitants until the whole territory acquires something approaching to an average amount of cultivation. Again, in every Country increased wealth and numbers are accompanied by increased agricultural skill and improved means of transport. The use of implements, the division of labour, and physical knowledge are powerful aids to the agriculturist, though they do not afford to him the almost magical increase of power which they give to the manufacturer. The improvements in carriage are still more important: a given amount of labour applied for twenty years to a given piece of land would probably now produce a return four or five times as great as would have been obtained at the Conquest. But the labour necessary to transport that produce one hundred miles is probably now not one one-hundredth of what it was then. No improvements in husbandry instruments, or in breeding, or in the rotation of crops, have been so efficient as the substitution of the waggon, the Macadamized road, the canal, the navigable river, and the railway, for the pack-horse of our ancestors and the dangerous tracks through which they beat out and picked their way. The intervention of a hill or a morass was then an obstacle sufficient to allow the price of corn on one side to be double that on the other; and London was so dependent on the immediately adjacent Counties that the landlords of those Counties petitioned against the opening of roads, as interfering with their vested right to a monopoly of the metropolitan supply; a petition which failed because the immediate interest of other landlords opposed it.

But the principal means by which a Country, when increasing in wealth and population, may avoid the necessity of raising its raw produce at a constantly increasing disadvantage is by importation.

We have seen that additional labour employed in manufactures produces an increasing proportionate effect; that if one thousand men can in a given time work up one million of pounds of cotton, two thousand men would be able to work up in the same time more than two millions of pounds, and four thousand men, much more than twice as much as two thousand. As a nation increases in opulence and population, it becomes the interest, therefore, of the community to devote their additional population rather to manufactures, in which they have a constantly increasing advantage, than to agriculture, at a constantly increasing disadvantage. As their industry becomes more and more efficient, they are in general able to purchase with the produce of a given amount of labour and abstinence larger and a larger amount of the produce of the industry of their less advanced contemporaries. The produce of the labour of a single Englishman employed for a given time in fabricating cotton will purchase the cotton grown by the labour of five, or perhaps ten, Hindoos, or the wheat grown by three, or perhaps five, Lithuanians or Poles.

It must be recollected, indeed, that a nation while extending its manufactures must increase its importation of raw produce; and we have already stated that the increased labour at which the additional produce must be obtained would retard the progress of such a community. But though this is unquestionable, though it is even certain that, if sufficient time be allowed, this obstacle is able, not merely to retard, but almost to arrest, the advance of manufactures, there seems to be little to fear from it within any of those periods within which calculations for practical purposes are generally confined. In the first place, the stimulus of an advantageous trade must tend to increase the agricultural skill of the exporting nations, and increase the facilities of transport; causes which, especially in the earlier stages of a nation's improvement, often enable it, and for considerable periods, to bring to market an increased quantity of raw produce with the same or even less proportionate labour. And, secondly, even if we suppose the manufacturing nation to be supplied by its agricultural customers at an increased proportionate expense to *them*, it does not follow that the proportionate expense to *her* need be increased. The increased difficulty on the one side may be balanced by the increased facility on the other. We will suppose that at present one hundred thousand yards of muslin, fabricated by twelve Englishmen, can be exchanged for one hundred and fifty quarters of wheat, raised by thirty-six Poles; that an increase in population of one-third makes it necessary to import two hundred instead of one hundred and fifty quarters, and that the two hundred quarters are raised, not by forty-eight, the former proportion, but by sixty Poles. If the increase in our skill has kept pace with our increase of numbers, it is probable that eighteen Englishmen, instead of one hundred and fifty thousand, the former proportion, would be able to fabricate at least two hundred thousand yards of muslin. The exchange under such circumstances, instead of being less, would be more beneficial than before. England would purchase more corn, and Poland more muslin, at a less proportionate amount of labour.

It must be carefully remembered that the preceding remarks apply not to the higher or lower *price* of raw produce, but to the greater or less difficulty in obtaining it; things which have no necessary connection; one of them depending on the causes which affect the general value of raw produce, the other on the causes which affect the general value of money. At the same time, and in the same place, the prices of articles exactly measure the difficulty of obtaining them. It is exactly half as difficult to get a commodity that costs one sovereign as to get a commodity that costs two. But this is only true at the same time and in the same place. Though in England a quarter of corn now costs about fifty shillings, and in the reign of Henry VIII. cost about twenty, it is probable that it was then more difficult to obtain one than it is now. This must have been the case if it was then more difficult to obtain twenty shillings than it is now to obtain fifty. It is equally clear that, although a quarter of wheat now costs in England about ten ounces of silver, and about six ounces in Poland, yet, if it is easier in England to obtain ten ounces of silver than in Poland to obtain six ounces, it is easier in England to obtain a quarter of wheat than it is in Poland. Experience shows that wealth and population almost always increase together, though not in equal ratios, the increase of wealth being, as we have already stated, generally greater than the increase of population. The increased capital and labour of an in-

creasing population are naturally directed to manufactures, in which, as we have already seen, every increased production is more easily effected. As their labour becomes more productive, the value of the products of a given quantity of that labour rises in the general market of the world; or, in other words, they obtain in return for it a greater amount of the precious metals; or, in other words, a higher price. Therefore, although they may have to pay a higher price for a given quantity of raw produce, whether of home growth or imported, it does not follow that the difficulty of obtaining that given quantity has increased; it is possible, and not improbable, that it may have diminished. A nation so situated may be compared to an individual whose income happens to be rising at the same time when the price of corn is rising. If the rise of his income more than counterbalances the rise of corn, he finds it every year more easy to purchase a given quantity, though he may have to give a higher and higher price for it.

We have seen that production may take place under five different circumstances.

1. Absence of monopoly; all persons being capable of producing with equal advantage.

2. A monopoly under which the monopolist has not the exclusive power of producing, but exclusive facilities as a producer, which may be employed indefinitely with equal or increasing advantage.

3. A monopoly under which the monopolist is the only producer, and cannot increase the amount of his produce.

4. A monopoly under which the monopolist is the only producer, and can increase indefinitely, with equal or increasing advantage, the amount of his produce.

5. A monopoly under which the monopolist is not the only producer, but has peculiar facilities which diminish and ultimately disappear as he increases the amount of his produce.

The price of those commodities which are comprehended in the first class appears to be subject to laws capable of accurate investigation. Where labour alone has been employed, the price must be equal to the wages of that labour. Where that labour has been assisted by abstinence, or, in other words, where a period has elapsed between the employment of the labour and the sale of its produce, the price must be equal to the amount of the wages of that labour and the remuneration to be paid either to the labourer for having suffered the payment of his wages to be deferred, or to the capitalist who has paid those wages in advance.

There are, however, very few commodities of which the whole price can be resolved into the remuneration for the labour, or the abstinence, or both, which must be bestowed on their production.

Mere abstinence can produce nothing. Labour, or the agency of nature, must afford the subject with respect to which it is to be exercised. It is possible, indeed, that a natural agent universally accessible may sometimes afford a product of no value at first, but capable of becoming valuable by mere keeping; but no instance of the kind occurs to us, and some little trouble is generally requisite for the mere safe custody of any article.

Mere labour *does* produce a very few articles. The laver collected and sold on the coast of Devonshire is an example. It grows naturally on the unappropriated rocks within the influence of the tide, and in abundance practically unlimited. No instruments are necessary to gather or prepare it, and, as it will not keep, it is sold as soon as it has been collected and washed. The price of a given quantity consists, therefore, merely of the wages of those who gather, wash, and bring it to market.

A class of commodities, perhaps rather larger, but still inconsiderable when compared with the general mass, is produced by labour and abstinence, assisted only by those natural agents which are universally accessible. It is difficult, however, to point out an article, however simple, that can be exposed to sale without the concurrence, direct or indirect, of many hundred, or, more frequently, of many thousand different producers; almost every one of whom will be found to have been aided by some monopolized agent.

There are few things of which the price seems to consist more exclusively of wages and profits than a watch;* but if we trace it from the mine to the pocket of the purchaser, we shall be struck by the payment of rent (the invariable sign of the agency of some instrument not universally accessible) at every stage of its progress. Rent was paid for the privilege of extracting from the mines the metals of which it is composed; for the land which afforded the materials of the ships in which those metals were transported to an English port; for the wharfs at which they were landed, and the warehouses where they were exposed to sale; the watchmaker pays a rent for the land covered by his manufactories, and the retailer for that on which his shop is situated. The miner, the shipwright, the house-builder, and the watchmaker all use implements formed of materials produced by the same processes as the materials of the watch, and subject also in their different stages to similar payments of rent. The whole amount of all these different payments forms probably a very small portion of the value of the watch, but if we were to attempt to enumerate them they would be found subdivided into ramifications too minute for calculation. What remains consists of the wages of the workmen, and the profits of the capitalists who paid those wages in advance. The attempt to trace back these wages and profits to their earliest beginnings would be as vain as the attempt to enumerate all the payments of rent. In estimating, therefore, the value of a manufactured commodity, we seldom go further back than to the price paid by the manufacturer for his materials and implements, a price which must have included all previous payments of rent, wages, and profits.

We will now trace the causes which increase the value of those materials after they have been the property of the manufacturer. We will suppose a watchmaker's capital to consist of materials worth £500, that he has bought the land covered by his buildings for £500, and has expended £900 in erecting them, that his tools have cost him £100, and that an annual expense of £100 is necessary to keep his buildings and tools in repair. We will suppose him to employ ten workmen, each receiving at an average £100 a year, and that one year is the average period from the commencement to the sale of a watch. We will suppose that his ten workmen can annually convert his £500 worth of materials into five hundred watches, and that the average rate of profit in his business amounts to ten per centum per annum. To give him this profit it is clear that his watches must sell for

* It has been used by M. Canard, M. Flores Estrada, and Mr. M'Culloch, as an example of the value derived from labour alone.

Value of materials................	£500
Wages for a year..................	1000
Repairs for a year.................	100
	1600
Profit on the advance of these sums and on the value of the land, and buildings, and tools, for half a year, at ten per cent. per annum	155
	£1755

It will be observed that, although a year is supposed to elapse between the commencement and the sale of a watch, we suppose the cost of its production to have been advanced for only half a year. The fact is that some part of the advances must have been made for more, and some for less than half a year. Supposing a workman to have been employed on the watch for a year, and paid daily, he received his first day's wages one year before the watch was sold, but his last day's wages on the very day of the sale; six months, therefore, is the average period for which the whole were advanced before the sale; just as large a proportion having been advanced for a shorter as for a longer period.

It will be observed, too, that we suppose the whole value of the materials, repairs, and wages to be repaid, but only a profit on the value of the land, buildings, and tools. The first are annually expended by the capitalist, the second remain to be used as instruments of further production. The land is indestructible, and the damage done to the buildings and tools is paid for by the £100 supposed to be expended in repairs.

But the whole cost of production has not yet been enumerated.

In the first place, some wages must be allowed to the master watchmaker himself for his labour in superintending his business; and, secondly, some profit on the expense of his education. And as his knowledge and habits, which form his mental capital, will not survive him, something more than the average rate of profit is necessary to replace their value.

If we suppose the expense of his education to have amounted to £1000, and that it will be replaced with average profit by an annual return of £15 per cent., and the average wages of labour to be £30 a year, we have £180 to add to the price of the watches, and £9 more for the advance of this sum for half a year, making £1944.

The last source of expense is taxation, or, in other words, the wages and profits of those who have protected all the different producers of the watches from foreign and domestic violence and fraud. A considerable portion of the price paid by the watchmaker for his materials, tools, and buildings, probably consisted of the taxation to which those commodities had been previously subjected; but the taxation which we are now considering is that which he incurs during the year supposed to be employed in manufacturing the watch.

This is an expense little capable of previous estimation; partly because the expenses of government are subject to constant variation, and partly because no general principle regulates the proportions in which those expenses are divided among the contributors. In England they are in general imposed upon the persons using or producing certain commodities; upon the use, for instance, of a carriage or window, and upon the production of candles or glass. We will suppose the annual taxation imposed on the shop and other instruments of production used by the watchmaker to amount to £53 7*s*., the profit on the advance of this sum for half a year would exceed by a slight fraction £2 13*s*., together £56, making with the £1944, the amount of our previous calculation, the sum of £2000, the whole cost of production of the five hundred watches, or £4 a piece.

The different sums in this example have of course been taken at random; but we have thought it worth while to go through it partly as an instance of the calculations on which every manufacturer must found his estimate of the profit or loss likely to follow any given undertaking; and partly to show in how many shapes, labour, abstinence, and the agency of nature, or, in other words, rent, profits, and wages, are constantly reappearing in every productive process.

When we speak, therefore, of a class of commodities as produced under circumstances of equal competition, or as the result of labour and abstinence unassisted by any other appropriated agent, and consider their price as equal to the sum of the wages and profits that must be paid for their production, we do not mean to state that any such commodities exist, but that, if they did exist, such would be the laws by which their price would be regulated; and that so far as labour or abstinence, or both, are conducive to the production of any given commodity, it is to be considered as produced under circumstances of equal competition, and as worth the wages or profits, or both, with which that labour or abstinence, or both, must be remunerated.

The prices of the commodities comprised in the second, third, and fourth classes are but little governed by any general rules. The prices of those comprised in the second class cannot rise above the cost of production when unassisted by the monopolized agent, but have a tendency to approach the cost of production to the monopolist. The prices of those comprised in the third and fourth classes have no necessary limits, but approach much more nearly to the cost of production in the fourth class, where the monopolist can increase his produce, than in the third class, where nature strictly limits the amount that can be produced.

The price of the commodities comprised in the fifth and last class, those which are produced under what may be called unequal competition or qualified monopoly, where all persons may become producers, but every additional quantity is obtained at a greater proportionate expense, has a constant tendency to coincide with the cost of production of that portion which is continued to be produced at the greatest expense. The annual supply of London requires about one million five hundred thousand quarters of wheat. Of this quantity, perhaps fifty thousand can be obtained only by means of high cultivation, or very distant carriage, at an expense of about 50*s*. a quarter. While the wants and the wealth of the inhabitants of London are such as to make them require, and enable them to purchase, one million five hundred thousand quarters, and the expenses of carriage and cultivation remain unaltered, it is clear that the whole quantity, supposing it to be of uniform quality, must sell at the rate of 50*s*. a quarter. If it were to sell for less, the last fifty thousand quarters would cease to be produced, and the price would again rise in consequence of the deficiency of the supply. But of the whole one million five hundred thousand quarters, a portion, perhaps fifty thousand, might be produced by slightly cultivating the most fertile and

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best situated land, at the expense of 10*s*. a quarter. A hundred thousand may cost the producer 20*s*. a quarter, two hundred thousand 25*s*., two hundred thousand more 30*s*. a quarter, and the cost of production of all, except the last fifty thousand, must have been less than the 50*s*. for which they are sold. The difference between the price and the cost of production is *rent*. It is an advantage derived from the use of a natural agent not universally accessible. It is taken, therefore, by the owner of the agent by whose assistance it was obtained.

A portion of the whole supply, however, that portion which is produced at the greatest expense, is produced without any payment of rent. If the cost of producing and sending to market from a given farm be in the following proportions: for one hundred quarters £1000, for ninety more £100, for eighty more £100, for seventy more £100, for sixty more £100, for fifty more £100, for forty more £100, and for thirty-three and one-third of a quarter more £100, and the price per quarter is 60*s*., it is clear that the landlord's rent will be in the following proportions:

On the first	£100 expended	£200
On the second	100	170
On the third	100	140
On the fourth	100	110
On the fifth	100	80
On the sixth	100	50
On the seventh	100	20
	In all	£770

And it is equally clear that no rent can be paid by the farmer for the privilege of producing the last thirty-three one-third quarters, as the whole £100 for which it sells is absorbed by the cost of production. The last thirty-three one-third quarters will continue to be produced as long as the wants and the wealth of the purchasers render them willing and able to purchase a quantity of corn, the whole of which cannot be supplied unless this last and most expensive portion is produced. If those wants and wealth should increase, it might become necessary to raise an additional supply at a still further additional expense, at the cost, we will say, of £100 for only twenty quarters. But it is clear that this could not be done unless the price should be £5 a quarter, since that is the lowest price at which the cost of producing the last supply would be repaid. The price, indeed, would probably have previously risen to above £5 a quarter, since an interval must have elapsed between the increased demand occasioned by the increased wants and wealth of the purchasers and the increase of the supply. During that interval the price must have risen somewhat above the price at which it would settle when the additional supply had been obtained. The appearance of that additional supply would sink it to £5 a quarter, the cost at which that supply is produced, but it could not permanently fall below that price unless a diminution should take place either in the wants or wealth of the purchasers, or in the expenses of cultivation or conveyance.

All this appears almost too plain for formal statement. It is however one of the most recent discoveries in Political Science: so recent that it can scarcely be said to be universally admitted even in this Country, and that abroad it does not seem to be even comprehended. If any writer could be expected to be fully master of it it would be Say, the most distinguished of the Continental Economists, and the annotator on Ricardo. In his notes to the French translation of the *Principles of Political Economy and Taxation*, he constantly objects to Mr. Ricardo's reasonings, the fact that all cultivated land pays rent; as if such a fact were inconsistent with the existence of corn raised without the payment of rent. He repeats this objection in a note to a passage in which Ricardo has demonstrated its falsity. In the twenty-fourth chapter of the *Principles*, Mr. Ricardo examines Adam Smith's opinions on rent.

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"Adam Smith," observes Mr. Ricardo, "had adopted the notion that there were some parts of the produce of land for which the demand must always be such as to afford a greater price than what is sufficient to bring them to market; and he considered food as one of those parts.

"He says that 'land in almost every situation produces a greater quantity of food than what is sufficient to maintain all the labour necessary for bringing it to market, in the most liberal way in which labour is ever maintained. The surplus, too, is always more than sufficient to replace the stock which employed that labour, together with its profits. Something, therefore, always remains for a rent to the landlord.'

"But what proof does he give of this? No other than the assertion that 'the most desert moors in Norway and Scotland produce some sort of pasture for cattle, of which the milk and the increase are always more than sufficient not only to maintain all the labour necessary for tending them, and to pay the ordinary profit to the farmer or owner of the herd or flock, but to afford some small rent to the landlord.' Now of this I may be permitted to entertain a doubt. I believe that as yet in every Country, from the rudest to the most refined, there is land of such a quality that it cannot yield a produce more than sufficiently valuable to replace the stock employed on it, together with the profits ordinary and usual in that Country. In America we all know that this is the case, and yet no one maintains that the principles which regulate rent are different in that Country and in Europe. But if it were true that England had so far advanced in cultivation, that at this time there were no lands remaining which did not afford a rent, it would be equally true, that there formerly must have been such lands; *and that whether there be or not, is of no importance to this question, for it is the same thing if there be any capital employed in Great Britain on land which yields only the return of stock with its ordinary profits, whether it be employed on new or old land.* If a farmer agrees for land on a lease for seven or fourteen years, he may propose to employ on it a capital of £10,000, knowing that at the existing price of grain and raw produce he can replace that part of his stock which he is obliged to expend, pay his rent, and obtain the general rate of profit. He will not employ £11,000 unless the last £1000 can be employed so productively as to afford him the usual profits of stock. In his calculation whether he shall employ it or not, he considers only whether the price of raw produce is sufficient to replace his expenses and profits, for he knows that he shall have no additional rent to pay. Even at the expiration of his lease his rent will not be raised; for if his landlord should require rent, because this additional £1000 was employed, he would withdraw it, since by employing it he gets by the supposition, only the ordinary and usual profits which he may obtain by any other employment of stock." *Principles*, &c., 389—391.

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To this passage, M. Say affixes the following note: "This is precisely what Adam Smith does not admit, since he says that the worst land in Scotland gives to its proprietor a rent." We answer to M. Say: "This is precisely what Mr. Ricardo declares to be immaterial, since a portion of what is produced on a farm giving a rent of ten guineas an acre, may be produced without any rent being paid for the privilege of producing it."

It must be admitted, however, that the doctrine in question has often been stated in a form likely to confuse the dull or inattentive, and liable to the cavils of the uncandid. Mr. Ricardo, who, though not its discoverer, is its best known expositor, was led, both by his merits and his deficiences, into frequent inaccuracy of language. He was not enough master of logic to obtain precision, or even to estimate its importance. His sagacity prevented his making sufficient allowance for the stupidity or carelessness of his readers; and he was too earnest a lover of truth to anticipate wilful misconstruction.

Under the influence of these causes he is, perhaps, the most incorrect writer who ever attained philosophical eminence; and there are few subjects on which he has been guilty of more faults of expression than on rent.

He perceived that an increased will and power on the part of the community to purchase raw produce, and the impossibility of increasing the supply but at an increased expense, must necessarily raise rents, and must also occasion an extension of cultivation. Associating, therefore, in his own mind the ideas of the rise of rents and of the extension of cultivation, he has often spoken of them as if they stood in the relation of cause and effect: as if the extension of cultivation were a cause of the rise of rent, instead of being, as it obviously is, a means by which that rise is counteracted. The inaccuracy is so obvious that we can scarcely suppose it to have misled any reader of tolerable care and acuteness.

He has also too frequently used the expression "the corn raised *on land* paying no rent," as an equivalent for "the corn raised without the payment of rent." And when his opponents reply, as is true, that "in old Countries all land pays a rent," he has sometimes denied the truth of the reply, instead of showing, as he has done in the passage which we have quoted, that the doctrine is just as true when applied to a small district in which all the land is highly rented, as when applied to a colony where rent is the exception and freedom from it the rule.

Again, he has often spoken of the existence of rent as dependent on the cultivation of land of different degrees of fertility, or on the fact that the same land repays, with a proportionably smaller return, the application of additional capital. And yet it is clear that if we suppose the existence of a populous and opulent district of great but uniform fertility, giving a large return to a given expenditure of capital, but incapable of giving any return whatever on a less expenditure, or any greater return on a larger expenditure, such a district would afford a high rent though every rood of land and every portion of the capital applied to it would be equally productive.

We now proceed to consider some remarkable consequences of the proposition that additional labour when employed in manufactures is more, and when employed in agriculture less efficient in proportion; or, in other words, that the efficiency of labour increases in manufactures in an increasing ratio, and in agriculture in a decreasing ratio. And, consequently, that every additional quantity of manufactured produce is obtained, so far as the manufacturing it is alone concerned, at a less proportionate cost, and every additional quantity of agricultural produce is obtained, generally speaking, at a greater proportionate cost.

Different effects of increased demand on manufactured and raw produce.

So far as the price of any commodity is affected by the value of the new material of which it is formed, it has a tendency to rise, so far as the price consists of the remuneration to be paid for the labour and abstinence of those employed in manufacturing it, it has a tendency to fall, with the increase of population.

It is obvious that commodities of rude or simple workmanship are subject to the first rule, and the finer manufactures to the second. Bread may afford an instance of the first kind, and lace of the second. The average price in England of a half-peck loaf is now about 1*s*. 3*d*. Of this sum 10*d*., at least, may be assumed to be the price of the wheat; the wages and profit of the miller, baker, and retailer absorbing the remainder. If circumstances should arise, requiring the present supply of bread to be immediately doubled from our home-produce, it is obvious that the increased supply of wheat could not be obtained by merely doubling the amount of labour now employed in its production. It is impossible to say to what amount the increased difficulty of production would raise the price of wheat; we will, however, suppose it to be doubled, and the price of the wheat necessary to make a half-peck loaf to be 1*s*. 8*d*. instead of 10*d*.: at the same time the increased labour employed in its manufacture and sale would become more efficient. The miller and the baker would employ better instruments and a greater division of labour, and the retailer would be able to double his sales at little additional expense. The price of bread, so far only as its manufacture and retail is concerned, would be reduced perhaps one-fourth, or from 5*d*. to 3¾*d*. In which case, the whole result of the increased production would be that the half-peck loaf would sell for 1*s*. 11¾*d*. instead of 1*s*. 3*d*.

We will now see what would be the effect of an increased use of lace.

At the present price of lace and cotton, a pound of cotton worth, in the Liverpool-market, 2*s*., may be converted into a piece of lace worth 100 guineas. Suppose the consumption of lace to double, and the increased difficulty of producing the additional quantity of the cotton fit for lacemaking to raise its price from 2*s*. to 4*s*. a pound; the price of the lace, supposing it still to be manufactured at the same expense, would be raised one thousand and fiftieth part, or from £105 to £105 2*s*. But it is impossible to doubt that the stimulus thus applied to the production of lace would improve every process of the manufacture. We should probably much underrate the amount of that improvement if we were to estimate the consequent saving of expense at one-fourth; in which case the whole result of the increased production would be that the lace would sell for £78 17*s*. instead of £105; the same circumstances which would nearly double the price of bread would reduce by one-fourth the price of lace.

Another inference from the proposition in question is the difference between the effects of taxation when imposed on raw produce and when imposed on manufactured produce.

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Taxes on manufactured commodities ultimately raise the price, and that by an amount exceeding the amount of the tax. Taxes on agricultural produce in its unmanufactured state do not necessarily occasion any ultimate rise of price, and raise it, if at all, by an amount less than that of the tax.

The first proposition may be easily illustrated.

We will suppose a tax on watches of twenty-five per cent. on their value to have existed from the commencement of that trade. As there is no reason to suppose that the profits or the wages of master watchmakers or their workmen are, under present circumstances, above the average wages and profits of persons similarly employed, it is clear that, if such a tax had always existed, the price for the time being of watches must always have been one-fourth higher than it has been, or the trade of watchmaking would have been followed neither by labourers nor capitalists. It is clear also that such an increase of price must always have diminished or retarded in its increase the sale, and, consequently, the production of watches. But if fewer watches had been made, the smaller number would have been made at a greater proportionate expense. And the price of watches must have been higher than it actually has been, first by the amount of the tax, and secondly by the greater expensiveness of the more limited manufacture. It is equally clear that, after the removal of such a tax, the price of watches would sink, first by the amount of the tax removed, and secondly by the improvement in the manufacture consequent on an increased production. It is equally clear that, if such a tax were now for the first time to be imposed, the price of watches must rise, first by the amount of the tax, and secondly by the amount of the increased proportionate expense of making and selling the diminished quantity sold, or watchmaking would cease to be as profitable as the average of trades. It is clear, too, that the more the use of watches diminished the higher the price must eventually rise. If only ten new watches were made every year, they would probably cost £500 a-piece. If only one were made, it would probably cost little less than the whole price of the ten. It is true that these effects would not immediately follow either the imposition or the removal of the tax: an interval must in either case elapse, during which, the existing capital in the watchmaking trade continuing the same, the supply of watches would be neither increased nor diminished, and, consequently, the price but little affected. During this interval, both the wages and the profits of those engaged in that business would be unnaturally high, or unnaturally low, and they would not acquire their natural level until, in the case of the removal of the tax, a sufficient number of persons were educated to the business, or, in the case of the imposition of the tax, the number of persons educated to the business had been sufficiently diminished, to enable the supply of watches to be proportioned to the demand, at a price giving average profits and wages to the capitalists and labourers employed in their manufacture and sale.

Effect of taxation on agricultural produce

But if agricultural produce were subjected to such a tax, relief would be afforded by precisely the same conduct which in manufactures aggravates the pressure, namely, by a diminution of production.

It may be assumed that capital is fairly distributed among the various channels for its employment, and that, in the absence of peculiar disturbing causes, agriculture, the most agreeable of all occupations, has not less than an average share of it. It may therefore be assumed, generally speaking, that capital is employed on land until its produce repays, but does not more than repay, the expense of cultivation; or, in other words, that the occupier of land pushes its cultivation until the additional produce obtained by means of the last labourers employed is just sufficient, at the existing price, to pay their wages, and average profits to himself, for the time during which those wages must be paid in advance. On the imposition of a tax, either the price of what he produces must rise by the amount of the tax, or the farmer must discontinue the production of that portion of his crop which is raised at the greatest expense.

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We will suppose a farmer to occupy a farm containing six hundred acres of arable land of different degrees of fertility; one hundred acres of which, with the labour of ten men directly and indirectly employed on them, would give a return which, in order to reduce it to one denomination, we will call six quarters of wheat an acre; one hundred others capable of giving with an equal number of men only five quarters per acre; one hundred others, four quarters per acre; one hundred others, three quarters per acre; one hundred others, two quarters per acre; and the last and worst one hundred acres, only one quarter per acre. We will suppose, also, that the wages of ten men for a year amount at an average to £400, or £40 a man; that the farmer has to advance these wages for a year before the produce is sold; and that the average rate of profit in similar occupations, is ten per cent. per annum. Under such circumstances, when wheat was £2 4*s.* a quarter it would be worth his while to employ every man whose labour produced twenty quarters, the price of which would amount to £44, being £40 for the labourer's wages, and £4 for the farmer's profit. The forty men supposed to be employed on the four best qualities of soil produce each this amount and more; the ten men employed on the fifth quality of soil produce each precisely this amount, namely, a return of two hundred quarters, worth £440. The sixth and last quality of soil, on which one man could produce only ten quarters, would not repay the cultivation of wheat. Now, if a tax were laid on raw produce, which, to make the illustrations less complex, we will call a tax of 14*s.* 8*d.* on every quarter of wheat, and no rise of price should take place, it is obvious that it would no longer be worth his while to cultivate any land of worse quality than that in which the labour of ten men could produce three hundred quarters of corn; a return which, at the existing price of £2 4*s.* a quarter, would procure £660, being £220 for the tax, and £440 as before for wages and profits. But it would obviously be worth his while to cultivate land of that quality, and also to employ labour in the cultivation of his superior land up to the point of which the labour of an additional man would no longer produce an additional produce of thirty quarters. Nothing but a tax so great as absolutely to prohibit agriculture, such a tax as never has existed, and which would, in fact, be rather a penalty than a tax, could induce him to discharge all his labourers, and leave his best land uncultivated. We do not deny that he would be a loser, even by the conduct which we have supposed him to adopt. We do not deny that he would much have preferred a rise in the price of corn equal to the tax,—a rise which would have enabled him to continue in its existing investment all his agricultural capital. But we deny that any imposition to which the name of a tax can fairly be applied, though unaccom-

panied by a rise of price, would induce him altogether to discontinue production. And we wish to draw the attention of our readers to the contrast between his situation and that of the manufacturer, whom any tax, however slight, if unaccompanied by a rise of price, must in time force to discontinue manufacturing. What is a remedy to the agriculturist is an aggravation of evil to the manufacturer; a diminution of capital makes what remains in agriculture more productive, and makes what remains in manufactures less so.

It has been supposed, however, that the price of agricultural produce would rise to the full amount of the tax, and that the whole amount of that tax would consequently fall on the consumer. This is the opinion of Mr. Ricardo and of Mr. Mill. And it is on this ground that they both maintain that the effect of tithes is to produce a rise in the price of raw produce equal to the whole value of the tithe, and affecting equally all classes so far as they are consumers of raw produce. We believe that the *immediate* effect of a general tax on raw produce is to raise its price, but to an amount not equal to that of the tax; but that its *ultimate* effect is to diminish the consumption and production of raw produce, but to leave its price unaffected

To prove our first proposition we need only show that the rise of price, which we admit to be the immediate consequence of the imposition of the tax, would diminish the consumption, and consequently the production of the taxed commodity. It has been shown already that, as production is diminished, the expense of producing the quantity still produced is diminished; and that the price of agricultural produce depends on the expense of producing that portion of it which is produced at the greatest expense, or, in other words, under circumstances of equal competition. That no person would diminish his consumption of corn in consequence of the rise of its price, is therefore a premise necessary to the conclusion which we are combating. This is true as respects that portion of the population of England which is dependent on parochial relief. In those districts in which the amount of that relief is calculated with reference to the price of bread, their means of purchasing are unconnected with price, and neither rise with its fall nor sink with its rise. It is true, also, as respects the families of those opulent individuals (a prominent, but in fact a small portion of society) whose direct expenditure in bread and flour bears a small proportion to their general expenses. But the bulk of the community, consisting of the labourers who receive no parish assistance, and happily they are now the majority, and we trust will soon be the great majority; and the smaller shopkeepers and farmers, unquestionably regulate, in a great measure, their purchases of wheat by its price. Much of their consumption, when it is comparatively cheap, consists of puddings and pies, articles of mere luxury, which, on the slightest rise, are immediately discontinued. If the rise continue, they turn from wheaten bread to cheaper subsistence: in the North to oatmeal, in the South to potatoes. And, indeed, without recurring to details, it may be laid down as a principle of universal application, that, in the absence of disturbing causes, every increase in the price of a commodity must diminish both the ability and the will to purchase it.

We now proceed to prove our second proposition, namely, that the ultimate effect of a tax on raw produce is not to raise its price, but to diminish the quantity produced. It will be at once admitted that the price of raw produce, in any Country, does not depend on the positive extent, or on the positive fertility of that Country, but, all the other things remaining the same, on the proportion which that extent, or that fertility bears to the number and wealth of the existing inhabitants. It may be low in a barren territory, if that territory be thinly peopled, just as it may be high in a fertile and populous one. It is high in the rich Lowlands of Scotland, and low in the sandy plains of Poland. And it will also be admitted that, all other things remaining the same, the population of a Country is in proportion to its extent and its fertility. Now, the ultimate effect of tithes, or of any other tax, on the cultivation of land is precisely the same as if the Country in which they have long prevailed were thereby rendered rather less extensive, or rather less fertile, and consequently, rather less populous, and probably also rather poorer than it otherwise would have been.

If England, from time immemorial, had been rather more extensive, or rather more fertile than it now is, no one will suppose that the price of provisions would have been lower than it now is. We should have had rather more corn, and a rather greater population to eat that corn, than we now have. The increase would have been positive, not relative. So if Devonshire or Lincolnshire had never existed, the agricultural produce and the population of England would each have been positively diminished; but, as they would have borne the same proportion to one another as they do now, the price of the existing quantity of corn could not have been higher than it is now. So if tithes had never existed, we should have had rather more corn, and a rather larger and probably a rather richer population; every thing else would have been as it is. It is true that, if a new Devonshire, or a new Lincolnshire, fit for immediate cultivation, were now suddenly added to our shores, the immediate consequences would be, an increased supply of provisions, and a fall in their price. But it is also true that, if this accession to our territory were followed by no change in our habits and institutions, the comparative cheapness, which would be its immediate consequence, would gradually disappear as our population rose with the increased supply of subsistence, and, ultimately, we should be just where we are now, excepting that we should be rather more numerous. So, if tithes were suddenly commuted, and their interference, such as it is, with agricultural improvement, got rid of, the same consequences would follow as if the extent of our territory, or its fertility were suddenly augmented. And, supposing no improvement to take place in our institutions and habits, the consequent increase of our population would bring us back, as far as the price of provisions is concerned, to the point at which we are now.

It is probable, indeed, that the ultimate effect of the abolition of tithes would be not a lowering but an increase of the price of raw produce. A denser population cultivating a territory, the productiveness of which had increased in proportion to the increased number of its inhabitants, would probably advance in opulence. The productiveness of the soil of a Country in proportion to its population being given, or, in other words, the amount of raw produce and the number of people being ascertained, the smaller the extent of the land from which that amount is obtained the better. The expenses of transport, and the trouble and loss of time in journeys, are material elements of the cost of production both in agriculture and in manufactures, and the amount of these expenses depends principally on the

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extent of Country affording a given return. As our industry became more efficient the value of our labour would rise in the general market of the world, and the consequence would be a general rise of prices, in which agricultural produce would participate. But these statements form no part of our argument. We believe, indeed, that the ultimate effect of tithes is to lower the price of raw produce: but all that we have undertaken to show is, that they do not raise it.

From these premises follow very important practical inferences. If we lay a tax on the production at home of any manufactured commodity which is produced with the same, or nearly the same, facility abroad, it is absolutely necessary that a duty of the same, or a rather greater amount, should be imposed on the importation of that commodity. On the imposition of the tax the cost of production at home is increased, first by the tax, and secondly by the increased expense of producing the smaller quantity which, when the price becomes higher, continues to be demanded. But if importation were untaxed, the cost of production abroad would be diminished in consequence of the diminished proportionate expense of producing the larger quantity demanded. The domestic production, and with the domestic production the tax, would not be merely diminished, but absolutely destroyed, and the whole result would be gratuitous evil. But when a tax, unbalanced by any countervailing duty on importation, is imposed on any agricultural produce for which a foreign substitute can be obtained, the only result is to stop *that portion which is most expensive* of the domestic production. The least productive part of the existing agricultural capital is withdrawn, or worn out without being replaced. The deficiency is attempted to be supplied by importation; but the increased demand instead of lowering, as would be the case with manufactures, raises the cost of production abroad, just as the diminished demand, instead of raising, lowers the cost of production at home. The price of agricultural produce rises until the state of the population has accommodated itself to the change, and then falls to its former level. If our present heavy tax on the domestic production of glass were unbalanced by any duty on importation, all the English glass-works would in time be abandoned. Or, if some of our glass-works were free from the tax, and others subject to it, all those which were taxed would be ruined. But the lands in England which are subject to the payment of tithes are not thrown out of cultivation by the competition of those which are free from that burden, or by the importation of the tithe-free corn and cattle of Scotland, or of the comparatively tithe-free produce of Ireland. The estates which are subject to tithes continue to be productive, they continue even to afford a rent, though the burden diminishes the productiveness, and diminishes in a still greater degree the rent.

Before we quit the subject of tithes, it may be worth while to expose another error connected with them, namely, the popular opinion that their tendency to increase in amount is greater than that of rent. We believe the fact to be just the reverse.

Tithes are a definite, rent is an indefinite, share of the produce. Tithes can never exceed a tenth; rent need not be a tenth, or even a hundredth, but may amount to a fourth, a third, a half, or even more than a half. Tithes, therefore, can be exacted, where rent cannot be; but when once any spot of land can afford to pay both rent and tithes, there is no comparison between their respective powers of increase. This will immediately appear on a reference to the familiar illustration of the progress of rent.

If we suppose a Country to be divided into ten districts designated by the numbers from 1 to 10, each of equal extent, but each of a different degree of fertility, No. 1 producing, at a given expense, two hundred quarters of corn, and the amount of the produce, at the same expense, of each quality of land, diminishing by ten quarters until we come to No. 10, which produces only one hundred quarters, we shall find that when No. 1 only will pay for cultivation, it affords twenty quarters for tithes, and no rent. When the price of corn has risen sufficiently to enable No. 2 to be cultivated, there will be on Nos. 1 and 2 thirty-nine quarters for tithes, and on No. 1 ten for rent. When No. 3 has become worth cultivation, there will be on Nos. 1, 2, and 3, fifty-seven for tithes, and on Nos. 1 and 2 thirty for rent. When No. 4 has become worth cultivating, there will be on Nos. 1, 2, 3, and 4, seventy-four for tithes, and on Nos. 1, 2, and 3, sixty for rent. When No. 5 has become worth cultivating, there will be on Nos. 1, 2, 3, 4, and 5, ninety for tithes, and on Nos. 1, 2, 3 and 4, one hundred for rent. Rent has now passed tithes, and its subsequent superiority is very striking. When No. 6 has become worth cultivating, there will be one hundred and five for tithes, and one hundred and fifty for rent. When No. 7 has become worth cultivating, there will be one hundred and nineteen for tithes, and two hundred and ten for rent. When No. 8 has become worth cultivating, tithes will be one hundred and thirty-two, and rent two hundred and eighty. When No. 9 has become worth cultivating, tithes will be one hundred and forty-four, and rent three hundred and sixty. And when No. 10 has become worth cultivating, tithes will be one hundred and fifty-five, and rent four hundred and fifty. And the same results will follow if, instead of supposing fresh land of a regularly decreasing fertility to be taken into cultivation, we suppose further capital to be applied to the same land, with a regularly decreasing proportionate return. Of course we do not mean that either of these suppositions represents what actually takes place, but they each represent the course of events to which there is a natural tendency. They represent the relative ratio at which rent and tithes would increase in the absence of disturbing causes. It must be recollected, however, that these events would not take place in the regular order in which we have placed them, except on the supposition of each different district which we have supposed to be successively cultivated being of the same extent, and of each successive application of capital being of the same value. If, for instance, No. 10 were ten times as large as any one of the other districts, and received ten times as much capital, it would increase the whole amount of titheable produce by one thousand quarters instead of by one hundred quarters, and tithes would be raised from one hundred and forty-four quarters to two hundred and forty-four quarters, while rent would have risen only from three hundred and sixty quarters to four hundred and fifty. In such an event, therefore, tithes would rise more than rent. And it must also be recollected that tithes and rent do not rise at precisely the same period. The highest amount of rent must be just *before* the land producing the additional supply has been cultivated. The increased demand is then in full operation, and has not been counteracted by the increased supply. But the amount of tithes is not increased until

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after the additional supply has been produced. Their increase, therefore, is generally contemporaneous with a temporary fall of rent: which is probably one of the causes of the popular opinion that their general tendency to increase is greater than that of rent. Another source of that opinion is, that in England the land has been for centuries subject to a constant process of subdivision, while tithes, except the comparatively small part which belongs to laymen, have not. The incumbent of a given benefice receives the tithes of the same quantity of land which was tithed by his predecessor three hundred years ago. But that land three hundred years ago may have belonged to one or two persons, and may now be divided between ten or twenty. The present incumbent's income may bear a higher proportion than his predecessor's did to the average income of a single landlord, though it bears a lower proportion to the aggregate income of all the landlords of the parish. And as a general proposition, we have no doubt that, in a progressive Country, the value of tithes will seldom increase in proportion to the increasing value of the land out of which they issue.

It appears, therefore, that in a new or ill-peopled Country where the abundance of land and the want of agricultural capital almost prevent the existence of rent, in the economical sense of the word, tithes are the only endowment which a Clergy can receive from the soil. We see, therefore, why they were adopted for the Israelites, who, in fact, were colonists, and by our Danish and Saxon ancestors. We see too why the attempt to endow with lands the Canadian Church has so signally failed. Tithes would not, perhaps, have been a politic, but they would have been an actual endowment. The reserves stand so many desert spots in the midst of improvements retarding the settlement, interrupting the communications, and injuring the wealth and civilization of all that is round them. Five centuries hence they might afford an ample provision.

Relative Proportions of Rent, Profit, and Wages.

Proportions of rent, profit, and wages. Nomenclature.

Having given a general outline of the three great classes among whom all that is produced is distributed, and of the general laws which regulate the comparative values of different products, we now proceed to consider the general laws which regulate the proportions in which landlords, capitalists, and labourers share in the general distribution, or, in other words, which regulate the proportions which rent, profit, and wages bear to one another.

We have followed the established nomenclature which divides society into landlords, capitalists, and labourers; and revenue into rent, wages, and profit. And we have defined rent to be the revenue spontaneously offered by nature or accident; wages the reward of labour; and profit that of abstinence. At a distance these divisions appear clearly marked, but when we look into the details, we find them so intermingled that it is scarcely possible to subject them to a classification which shall not sometimes appear to be inconsistent, and still more frequently to be arbitrary. But it must be remembered that questions of classification relate rather to language than to facts; and that our object will have been effected if we can assist the memory by supplying a precise and consistent nomenclature.

We will begin by recurring to a subject to which we have already alluded, the frequent difficulty of deciding whether a given revenue ought or ought not to be called rent. When an estate has been for some time leased to a careful tenant, it generally receives permanent ameliorations, which enable the owner, at the expiration of the lease, to obtain a higher rent. A bog worth 2*s.* annually an acre may be converted into arable or pasture worth annually £2. Is the increase of revenue rent or profit? It arises from an additional fertility, now inseparably attached to the land. It is received by the owner without sacrifice on his part. It is, in fact, undistinguishable from the previous rent. On the other hand, its existence is owing to the abstinence of the farmer, who devoted to a distant object, the amelioration of the land, labour which he might have employed in producing immediate enjoyment for himself. If the owner of the estate had farmed it himself, and had directed labour to be employed on its permanent improvement, the additional produce occasioned by those improvements would clearly have been termed profit. It appears, therefore, most convenient to term it profit when occasioned by the improvements made by a tenant.

In fact, these improvements are as consistently to be termed capital as a dock or a cotton-mill. Whose capital are they then? During the lease the capital of the tenant; when it has fallen in, the capital of the landlord, who has purchased them by engaging not to raise the rent during the currency of the lease.

We may be asked, then, whether the improvements which form the greater part of the value of the soil of every well-cultivated district are all, and for ever, to be termed capital? Whether the payments received from his tenants by the present owner of a Lincolnshire estate, reclaimed by the Romans from the sea, are to be termed, not rent but profit on the capital which was expended fifteen centuries ago? The answer is that, for all useful purposes, the distinction of profit from rent ceases as soon as the capital, from which a given revenue arises, has become, whether by gift or by inheritance, the property of a person to whose abstinence and exertions it did not owe its creation. The revenue arising from a dock, or a wharf, or a canal is profit in the hands of the *original constructor*. It is the reward of *his* abstinence in having employed capital for the purposes of production instead of for those of enjoyment. But in the hands of his heir it has all the attributes of rent. It is to him the gift of fortune, not the result of a sacrifice. It may be said, indeed, that such a revenue is the reward for the owner's abstinence in not selling the dock or the canal and spending its price in enjoyment. But the same remark applies to every species of transferable property. Every estate may be sold, and the purchase-money wasted. If the last basis of classification were adopted, the greater part of what every Political Economist has termed rent must be called profit.

Again, there are few employments in which extraordinary powers of body or mind do not receive an extraordinary remuneration. It is the privilege of talent to work not only better but more easily. It will generally be found, therefore, that the commodity or service produced by a first-rate workman, while it sells for more than an average price, has cost less than an average amount of labour. Sir Walter Scott could write a volume with the labour of about three hours a day for a month, and for so doing received £500 or £1000. An ordinary writer, with equal application, would find

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it difficult to produce a volume in three months, and still more difficult to sell it for £50.

Is then the extraordinary remuneration of the labourer, which is assisted by extraordinary talents, to be termed rent or wages? It originates in the bounty of nature; so far it seems to be rent. It is to be obtained only on the condition of undergoing labour; so far it seems to be wages. It might be termed, with equal correctness, rent, which can be received only by a labourer, or wages, which can be received only by the proprietor of a natural agent. But as it is clearly a surplus, the labour having been previously paid for by average wages, and that surplus the spontaneous gift of nature, we have thought it most convenient to term it rent. And for the same reason we term *rent* what might, with equal correctness, be termed fortuitous profit. We mean the surplus advantages which are sometimes derived from the employment of capital after making full compensation for all the risk that has been encountered, and all the sacrifices which have been made, by the capitalist. Such are the fortuitous profits of the holders of warlike stores on the breaking out of unexpected hostilities; or of the holders of black cloth on the sudden death of one of the Royal family. Such would be the additional revenue of an Anglesea miner, if, instead of copper, he should come on an equally fertile vein of silver. The silver would, without doubt, be obtained by means of labour and abstinence; but *they* would have been repaid by an equal amount of copper. The extra value of the silver would be the gift of nature, and therefore rent.

Secondly. It is still more difficult to draw the line between profit and wages. There are, perhaps, a few cases in which capital may improve in value, without superintendence or change, simply by being preserved from consumption. Wine and timber, perhaps, afford instances. But even a wine-cellar or a plantation, if totally neglected, would probably deteriorate. And, as a general rule, it may be laid down that capital is an instrument which, to be productive of profit, must be employed, and that the person who directs its employment must *labour*, that is, must to a certain degree conquer his indolence, sacrifice his favourite pursuits, and often incur other inconveniences from his residence, from the persons to whose contact he is exposed, from confinement or from exposure to the weather, and must also often submit to some inferiority of rank. If labour be in general necessary to the use of material capital, it is universally necessary to the use of that immaterial capital which consists of appropriate knowledge, and of moral and intellectual habits and reputation.—A capital created and kept up at more expense, and productive of a greater return than that which is material, but which, from the impossibility of actually transferring it, or implanting in one man the ability of another, can never be productive but through the labour of its possessor.

Is then the remuneration of this labour to be termed wages or profit? A certain portion of it, that portion which would be sufficient to repay equal exertions and hardships endured by an ordinary labourer, unprovided with capital, must, without doubt, be termed wages. And where extraordinary natural talents or favourable accidents have occasioned the exertions of the capitalist to obtain more than an average remuneration, that excess is, as we have already seen, rent. But the revenue to which our present question applies is the revenue obtained from the employment of capital, after deducting ordinary interest on the capital, as the remuneration for the abstinence of the capitalist, ordinary wages, as the remuneration for his labour, and any extraordinary advantages which may have been the result of accident.

The subject may be made clearer by a few examples; and we have endeavoured to find some in which the remuneration for the capitalist's trouble, instead of being, as is usually the case, mixed up with the gross amount of his returns, appears as a separate item. The trade of bill-broking affords an instance. The business of a bill-broker is to advance, before it becomes due, the money for which bills of exchange are drawn, deducting, under the name of discount, interest at the rate of not more than five per cent. per annum on the sum secured by the bill. In time of peace, and in the ordinary state of the money-market, the rate of discount varies from four to three per cent. per annum. It has been sometimes as low as two and a half. It appears at first strange that such a trade should exist, since the money capital employed in it does not return even so high a profit as may often be obtained from the public funds, leaving the additional risk and labour uncompensated. It is, in fact, a trade which no one *would* carry on if he employed in it his own money.

The commercial inhabitants of a great trading city have from time to time under their control considerable sums of money for short periods. Scarcely a single estate in this Country is mortgaged or sold without the price or the mortgage-money being placed for some days at a banker's or agent's until the "more last words" of the lawyers have been said. These sums cannot in the mean time be employed in any permanent investment; but they can be lent from day to day, or, in some cases, from week to week, and it is better to lend them at the lowest rate of interest than to suffer them to lie perfectly idle. The bill-broker's trade is to borrow these sums from week to week, or even from day to day, at one rate of interest, and to lend them from month to month, or for two or three months, at a higher. To borrow, for instance, at two per cent. and to lend at three.

It is obvious that these operations require much knowledge, industry, and skill. The broker must be well acquainted with the circumstances of almost every eminent commercial man in order to estimate the value of his acceptance or indorsement. He must keep up his knowledge by unremitting observation, and by inferences drawn from very slight hints and appearances. He must also have the skill so to manage his concerns as to have his receipts always falling in to correspond with his engagements. This knowledge, and the moral and intellectual habits which enable him to apply it, form his personal or immaterial capital. But he must also have a material capital, not for the purpose of being employed in his business, for no one would so employ money of his own, but as the means of obtaining confidence. The interest paid by a broker is so trifling that no one would lend to him if it implied the slightest risk; and the best pledge which he can give is the notoriety of his possessing a large capital, which could at any time make good an unforeseen interruption in his regular receipts. This capital he must not waste, but he may employ it productively, and may consume on himself the annual profit derived from it. The confidence which it enables him to enjoy is a distinct advantage.

We will suppose a bill-broker to possess £100,000 in the Four per Cents; and to have sufficient knowledge, skill, and character as a man of business and of wealth, to be able, at an average throughout the year, to borrow

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£400,000 at two per cent., and to lend the same sum at three per cent. Is the £4000 a year which his business would give him wages or profit?

Again, a capital which in this Country would enable its employer to obtain ten per cent., would often, if he were to employ it in Jamaica or Calcutta, produce fifteen or twenty. If the capitalist with £50,000 encounter the climate and the society of Jamaica, and is rewarded by his annual returns being raised from £5000 to £7500, is his additional income of £2500 a year wages or profit?

There is no doubt that a sufficient portion of it to purchase the same services from a person unprovided with capital, must be considered as wages: £500 a year, however, would considerably exceed this sum. The remaining £2000 a year may be considered, with equal correctness, either wages which can be received only by the possessor of £50,000, or profit which can be received only by a person willing to labour in Jamaica.

Adam Smith considers it as profit. "The profits of stock," he observes,* "it may, perhaps, be thought, are only a different name for the wages of a particular sort of labour, the labour of inspection or direction. They are, however, altogether different, are regulated by quite different principles, and bear no proportion to the quantity, the hardship, or the ingenuity of this supposed labour of inspection and direction. They are regulated altogether by the value of the stock employed, and are greater or smaller in proportion to this stock. If we suppose two manufacturers, the one employing a capital of £1000 and the other one of £7300, in a place where the common profits of manufacturing stock are ten per cent., the one will expect a profit of about £100 a year, while the other will expect about £730. Yet their labour of inspection may be very nearly or altogether the same. In many great works, almost the whole labour of this kind is committed to some principal clerk. His wages properly express the value of this labour of inspection and direction. Though in settling them some regard is commonly had, not only to his labour and skill, but to the trust which is reposed in him, yet they never bear any regular proportion to the capital of which he oversees the management. And the owner of this capital, though he is thus discharged of almost all labour, still expects that his profits should bear a regular proportion to his capital."

After much hesitation, we have resolved to adopt this as the most convenient classification, and to confine the term wages to the remuneration for simple labour; including under the word labour the endurance of all its attendant hardships, but excluding from the word wages the additional revenue which the labourer often receives because he happens to be also a capitalist. We have done so on the grounds which are so ably stated in the passage which we lastly quoted.

To revert to our supposition of a capitalist with £50,000 repaid by an extra revenue of £2500 a year for living in Jamaica: it is clear that another capitalist taking there £100,000 would, *cæteris paribus*, obtain an extra revenue of £5000 a year, and *that* notwithstanding his labour would not necessarily be greater than that of the first-mentioned capitalist, or notwithstanding it might in fact be much less. Perhaps the best plan might appear to be, to apply the term *wages* to the remuneration of mere labour, the term *interest* to the remuneration of mere abstinence, and the term *profit* to the combination of wages and interest, to the remuneration of abstinence and labour combined. This would make it necessary to subdivide capitalists into two classes, the inactive and the active: the first receiving mere interest, the second obtaining profit.

In this, however, as in many other cases, the inconveniences occasioned by departure from an established nomenclature and an established classification are so great, that we do not think that they will be compensated by the nearer approach to precision. We shall continue, therefore, to include under the term profit the whole revenue that is obtained from the possession or employment of capital, after deducting those accidental advantages which we have termed rent, and also deducting a sufficient sum to pay to the capitalist, if actively employed, the wages which would purchase an equal amount of labour from a person unpossessed of capital. In one respect, however, we are forced to differ from Adam Smith. Although he considers the useful, acquired knowledge and abilities of all the inhabitants of a Country as part of the national fortune, as a capital fixed and realized in the persons of their possessors, yet he generally terms the revenue derived from this capital *wages*. "The average and ordinary rates of profit in the different employments of stock are," he observes, "more nearly on a level than the wages of the different sorts of labour. The difference between the earnings of a common labourer and those of a well-employed lawyer or physician, is evidently much greater than that between the ordinary profits in any two different branches of trade." Book i. ch. x.

According to our nomenclature (and indeed according to that of Smith, if the produce of capital is to be termed profit) a very small portion of the earnings of the lawyer or of the physician can be called wages. Forty pounds a year would probably pay all the labour that either of them undergoes, in order to make, we will say, £4000 a year. Of the remaining £3960, probably £3000 may in each case be considered as rent, as the result of extraordinary talent or good fortune. The rest is profit on their respective capitals; capitals partly consisting of knowledge, and of moral and intellectual habits acquired by much previous expense and labour, and partly of connection and reputation acquired during years of probation while their fees were inadequate to their support.

Under this view of the case the revenue which consists of profit will in the progress of improvement bear a constantly increasing proportion to that which consists of wages. There appears no reason to doubt that, as civilization advances, every person will receive an education which will materially increase his power of production. Brutes and machinery can effect almost every thing that is to be effected by mere bodily exertion. Whatever requires mind, will be done better in proportion as the mind has received earlier or more judicious cultivation. We have heard it made a subject of complaint, that the uneducated Irish have dispossessed the English of the lowest employments in London and its neighbourhood. We rather rejoice that the English are sufficiently educated to be fit for better things. If they had remained as ignorant as their rivals, many who are now earning 40*s*. a week as mechanics, might have been breaking stones and carrying hods at 2*s*. a day. Even in our present state of civilization, which, high as it appears by comparison, is far short of what may easily be conceived, or even of what may confidently be expected, the intellectual and moral capital

* Book i. ch. vi.

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of Great Britain far exceeds all her material capital, not only in importance, but even in productiveness. The families that receive mere wages probably do not form a fourth of the community; and the comparatively large amount of the wages even of these is principally owing to the capital and skill with which their efforts are assisted and directed by the more educated members of the society. Those who receive mere rent, even using that word in its largest sense, are still fewer: and the amount of rent, like that of wages, principally depends on the knowledge by which the gifts of nature are directed and employed. The bulk of the national revenue is profit; and of that profit the portion which is mere interest on material capital probably does not amount to one-third. The rest is the result of personal capital, or, in other words, of education.

It is not on the accidents of soil or climate, or on the existing accumulation of the material instruments of production, but on the quantity and the diffusion of this immaterial capital, that the wealth of a Country depends. The climate, the soil, and the situation of Ireland have been described as superior, and certainly are not much inferior, to our own. Her poverty has been attributed to the want of material capital; but were Ireland now to exchange her native population for seven millions of our English North Countrymen, they would quickly create the capital that is wanted. And were England, North of Trent, to be peopled exclusively by a million of families from the West of Ireland, Lancashire and Yorkshire would still more rapidly resemble Connaught. Ireland is physically poor because she is morally and intellectually poor, because she is morally and intellectually uneducated. And while she continues uneducated, while the ignorance and violence of her population render persons and property insecure, and prevent the accumulation and prohibit the introduction of capital, legislative measures, intended solely and directly to relieve her poverty, may not indeed be ineffectual, for they may aggravate the disease, the symptoms of which they are meant to palliate, but undoubtedly will be productive of no permanent benefit. Knowledge has been called power; it is far more certainly wealth. Asia Minor, Syria, Egypt, and the Northern coast of Africa, were once among the richest, and are now among the most miserable Countries in the world, simply because they have fallen into the hands of a people without a sufficiency of the immaterial sources of wealth to keep up the material ones. "In what way," asks Adam Smith, "has Europe contributed to the grandeur of the colonies of America? In one way, and in one way only, she has contributed a great deal. *Magna virum mater.* She bred and formed the men who were capable of achieving such great actions, and of laying the foundation of so great an empire; and there is no other quarter of the world of which the policy is capable of forming, or has ever actually and in fact formed such men. The colonies owe to Europe the education and great views of their active and enterprising founders, and some of the greatest and most important of them owe to her scarce any thing else."

Proportionate Amount of Rent.

Rent.

We have already defined rent to be the revenue spontaneously offered by nature or accident, or, in other words, to be the price paid for the assistance of an appropriated natural agent. It might with equal propriety be defined the surplus produce arising from the use of an appropriated natural agent, or the amount by which the price of the produce of an appropriated natural agent exceeds the costs of its production.

The nature and the progress of the rent of land have usually been illustrated by supposing lands of different fertility to be successively taken into cultivation. Thus the land No. 1 is supposed to afford, in return for the application of a given amount of labour and capital, one hundred quarters; No 2, ninety quarters; No. 3, eighty quarters; No. 4, seventy quarters; No. 5, sixty quarters; and so on. While any portion of the most fertile lands is unappropriated, No. 1 only is cultivated, and no rent is paid. Before it has become necessary to cultivate No. 2, No. 1 must have become an appropriated agent, affording a larger return than can be obtained without its assistance. Its owner, or, as he is termed, the landlord, obtains, therefore, the value of that assistance, being ten quarters, or the difference between one hundred quarters and ninety quarters; and receives it himself, in kind, if he himself is the cultivator, or is paid for it the remuneration termed "rent," if he allows another person to be the cultivator. Before it has become necessary to cultivate No. 3, the rent of No. 1 must have risen from ten quarters to twenty, and No. 2, from giving no rent, must have given a rent of ten quarters; and so on until the point is reached at which the labour and capital employed will produce a return only sufficient to give a bare subsistence to the labourer and average profits to the capitalist: the highest extreme to which cultivation can be intentionally pushed, and one, indeed, beyond which it is seldom carried.

It is obvious, therefore, that the amount of rent depends on two causes: 1. the positive productiveness of the natural agent by which it is afforded; 2. the comparative productiveness of that agent, or the degree in which it exceeds those agents which are universally accessible. If the supply of natural agents were unlimited, or if their power of affording assistance were to cease, in either case rent would be at an end. Rent is the value of their assistance, and that value, like all others, depends partly on their utility, and partly on their limitation of supply. Much error has arisen from attending to only one of these causes.

The French Economists* perceived that the produce

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* *Le laboureur est le seul dont le travail produisse au delà du salaire du travail. Il est donc l'unique source de toute richesse.*

La terre, indépendamment de tout autre homme et de toute convention, lui paie immediatement le prix de son travail. La nature ne marchande point avec lui pour l'obliger à se contenter du nécessaire absolu.—Ce qu'elle donne n'est proportionnée ni à ses besoins ni à une évaluation conventionnelle du prix de ses journées. C'est le résultat physique de la fertilité du sol, et de la justesse, bien plus que de la difficulté des moyens, qu'il a employés pour le rendre fécond. Dès que le travail du laboureur produit au delà de ses besoins, il peut, avec ce superflu que la nature lui accorde en pur don, au delà du salaire de ses peines, acheter le travail des autres membres de la société. Ceux-ci en le lui vendant ne gagnent que leur vie, mais le laboureur recueille outre sa subsistence une richesse disponible; qu'il n'a point achetée, et qu'il vend. Il est donc l'unique source des richesses, qui, par leur circulation, animent tous les travaux de la société; parcequ'il est le seul dont le travail produisse au delà du salaire du travail.

Il reste donc constant qu'il n'y a de revenu que le produit net des terres, et que tout autre profit annuel, ou est payé par le revenu, ou fait partie des frais qui servent à produire le revenu.—Turgot vol. v. p. 8—9—126.

Vous ne pouvez trouver le meilleur état possible d'une nation, que dans la plus grande richesse possible. *J'entends ici par la terme de richesse, une masse de valeurs* disponibles, *de valeurs qu'on puisse*

of fertile land, the most important of all appropriated natural agents, sells for a price exceeding the expense of its cultivation. This excess of price, or *produit net*, as they termed it, they conceived to be the only source of wealth. All other commodities appeared to them merely to represent the toil employed in their acquisition. They believed, therefore, a community to be rich in proportion to the amount of rent received by the proprietors of its land; and consequently that production enriches only so far as it is subservient to the creation of rent.

It is impossible that they could have maintained this doctrine, if they had perceived that abundance is an element in wealth, and that high rents and the greatest abundance are incompatible; or if they had recollected that, according to their views, a community possessing the highest skill and exerting the utmost diligence, but scattered over a territory of unbounded extent and fertility, as they might be even unacquainted with the existence of such a thing as rent, must be totally without riches, must be poor from the mere prodigality of their resources.

In the following passage Mr. Ricardo seems to have fallen into an opposite error.

"Nothing is more common than to hear of the advantages which the land possesses over every other source of useful produce, on account of the surplus which it yields in the form of rent. Yet, when land is most abundant, when most productive, and most fertile, it yields no rent; and it is only when its powers decay, and less is yielded in return for labour, that a share of the original produce of the more fertile portions is set apart for rent. It is singular that this quality in the land, which should have been noticed as an imperfection, compared with the natural agents by which manufactures are assisted, should have been pointed out as constituting its peculiar pre-eminence. If air, water, the elasticity of steam, and the pressure of the atmosphere, were of various qualities, if they could have been appropriated, and each quality existed only in moderate abundance, they, as well as the land, would afford a rent, as the successive qualities were brought into use. With every worse quality employed, the value of the commodities in the manufacture of which they were used would rise, because equal quantities of labour would be less productive. Man would do more with the sweat of his brow, and nature would perform less; and the land would be no longer pre-eminent for its limited powers.

"If the surplus produce which the land affords in the form of rent be an advantage, it is desirable that every year the machinery newly constructed should be less efficient than the old, as that would undoubtedly give a greater exchangeable value to the goods manufactured, not only by that machinery, but by all other machinery in the Kingdom; and a rent would be paid to all those who possessed the most productive machinery.

"The labour of nature is paid not because she does much, but because she does little. In proportion as she becomes niggardly in her gifts, she exacts a greater price for her work. Where she is munificently beneficent she always works gratis." *Principles*, p. 63.

Mr. Ricardo seems to have forgotten that the quality which enables land to afford rent, namely, the power of producing the subsistence of more persons than are required for its cultivation, is an advantage without which rent could not have existed. As the population of any given district becomes more dense, the surplus produce of its soil, or, in other words, the amount of its produce which remains after provision has been made for the subsistence of those by whom it is cultivated, has a constant tendency to increase; either because the increase of agricultural skill and capital increases its positive fertility, or because a diminution of its relative fertility, a diminution of its produce relatively to the numbers of its cultivators, forces the poorer classes to be satisfied with a less amount of raw produce; or from both these causes combined. Of these two causes of rent, one is a benefit, the other an evil. That we have in this Country perhaps a million of acres capable of producing, with average labour, forty bushels of corn an acre, is a benefit; that we have not more than a million such acres is an evil. That the average amount of what an agricultural labourer produces much exceeds what is absolutely necessary for the subsistence of an agricultural family is a benefit. That the extent of our fertile land, and the amount of our capital, in proportion to our population, are not sufficient to enable him to consume, directly or indirectly, for his own advantage and that of his family, *all* that he produces, is an evil. To produce rent, both the benefit and the evil must coexist. The one occasions rent to be demanded; but it is the other which enables it to be paid.

Mr. Ricardo's attention seems to have been confined to the evil. But rent might be enormously increased without the increase of that evil, or even though that evil should be diminished. If the proprietor of a single estate could by a wish triple its produce, he would augment, in a much greater ratio, its rent. Would this increase be owing to the parsimony of nature? It may be said that it would be owing to the comparative unproductiveness of the rest of the Country. It must be admitted that, if we could suddenly triple the productive powers of all the land in this Country, the population remaining the same, the whole amount of rent would fall, and the condition of all classes, except of that comparatively small class which subsists on the rent of land, would be much improved. But if our population were also tripled, rents would be prodigiously increased, the situation of the landlords would be improved, and that of no other class deteriorated. In fact, the condition of all other classes would be improved, as the increased division of labour and ease of communication occasioned by a greater density of population would cheapen and improve our manufactures. If the population, instead of being tripled, were only doubled, the situation of the Country would be still better. The rise in rent, though not equal to what it would have been if the population had been tripled, would still be very great, and both raw produce and

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consommer au gré de ses désirs, sans s'appauvrir, sans altérer le principe qui les reproduit sans cesse.

Le meilleur état possible est évidemment celui auquel est attachée la plus grande sûreté; il consiste donc dans la plus grande masse possible de valeurs disponibles; car ce sont les seules dont nous puissions toujours jouir, et sur lesquelles la sûreté puisse s'établir.

Je voudrois bien que mes lecteurs donnassent à cette vérité toute l'attention qu'elle mérite, je voudrois bien qu'ils saisissent que la richesse ne consiste que dans les valeurs disponibles, *qu'on peut consommer sans aucun inconvénient; par conséquent, qu'il n'y a que le produit net des cultures qui soit richesse, parcequ'il est dans la masse des reproductions, la seule partie dont nous puissions disposer pour nos jouissances; le surplus de cette masse n'est pas disponible pour nous, il appartient à la culture, c'est elle qui tous les ans doit le consommer; nous ne pouvons le lui dérober, que nous n'en soyons punis par l'extinction de nos richesses.—L'Ordre Naturel, &c.*, p. 379—381.

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manufactures would be more abundant than they were previously. Now this is, in fact, what *has* occurred in England during the last hundred and thirty years. Since the beginning of the XVIIIth Century the population of England has about doubled. The produce of the land has certainly tripled, probably quadrupled. Rent has risen in a still greater proportion; but that rise has been accompanied by a rise of wages, estimated in every commodity consumed by the labourers, excepting a few, such as spirituous and fermented liquors, which have been made the subject of special taxation. With the same labour the labourer can obtain more corn, and perhaps five times as much of the most useful manufactures. Can it be fairly said that rents have risen because nature has done little? that the price paid for her assistance has been increased because she has become more niggardly in her gifts? It is true that, if the productiveness of the land, instead of being tripled, had been centupled, rents might not have risen; but it is equally true that they would not have risen if, instead of being tripled, it had remained stationary. The condition essential to the payment of the labour of nature is not, as Mr. Ricardo states it, that her assistance shall be little, but that it shall not be infinite.

As rent arises from the agency not of man, but of nature, its amount does not depend on the will or the exertions of its recipient. The owner of the land, or of the natural agent, whatever it be, for the use of which persons are willing to pay rent, receives the sum which their mutual competition forces them to give. As it is all pure gain, he accepts the largest sum that is offered, however trifling its amount. Nor, on the other hand, does the amount of rent depend on the will or the exertions of those who pay it. Whatever be the value of the services of an appropriated natural agent, that value must be paid by the person who wishes to use them, as both parties to the bargain are aware, that if it is not hired by one applicant it will be by another. The amount, therefore, is subject to no general rule; it has neither a minimum nor a maximum. It depends on the degree in which nature has endowed certain instruments with peculiar productive powers, and the number of those instruments compared with the number and wealth of the persons able and willing to hire them. There is, probably, now land near New York selling for £1000 an acre, which a century ago could have been obtained for a dollar.

Proportionate Amounts of Profit and Wages.

Proportions of profit and wages.

Profits and wages differ in almost all respects from rent. They are each subject to a minimum and a maximum. They are subject to a minimum, because each of them is the result of a sacrifice. It may be difficult to say what is the minimum with respect to profit, but it is clear that every capitalist, as a motive to abstain from the immediate and unproductive enjoyment of his capital, must require some remuneration exceeding the lowest that is conceivable. The minimum at which wages can be permanently fixed is of course the sum necessary to enable the existing labouring population to subsist. On the other hand, as the rate of wages depends in a great measure on the number of labourers, and the rate of profit on the amount of capital, both high wages and high profits have a tendency to produce their own diminution. High wages, by stimulating an increase of population, and therefore an increase of the number of labourers, and high profits, by occasioning an increase of capital. It will be seen in a future portion of this Treatise that, if the amount of capital employed in the payment of wages increases, the number of labourers remaining the same, profits will fall; and that if the number of labourers increases, the amount of capital and the productiveness of labour remaining the same, wages will fall; and that, if they both increase in equal proportions, both will have a tendency to fall, in consequence of the larger proportion which they will each bear to the power of the natural agents whose services they each require. And although it may not be easy to fix the maximum of either wages or profits, yet it may be laid down generally, that in no Country have profits continued for any considerable period at the average rate of fifty per cent. per annum, or wages at such a rate as to afford the labourer ten times the amount necessary for the subsistence of a family.

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Adam Smith has laid down, that "the whole of the advantages and disadvantages of the different employments of labour and capital must, in the same neighbourhood, be either perfectly equal or continually tending to equality. If in the same neighbourhood there was any employment evidently either more or less advantageous than the rest, so many people would crowd into it in the one case, and so many would desert it in the other, that its advantages would soon return to the level of other employments. This at least would be the case in a society where things were left to take their natural course, where there was perfect liberty, and every man was perfectly free both to choose what occupation he thought proper, and to change it as often as he thought proper. Every man's interest would prompt him to seek the advantageous and to shun the disadvantageous employment." *Wealth of Nations*, book i. ch. x.

The truth of these remarks of Adam Smith is obvious. It is obvious also that, in the absence of disturbing causes, the desire of obtaining a more advantageous field for the employment of his mental and bodily faculties, which leads a man to move from one part of the same neighbourhood to another, would lead him from village to village and from Country to Country. For commercial purposes, the whole civilized world is one extended neighbourhood; and the same causes which tend to equalize profits in Liverpool and London tend to equalize them in London and Calcutta. But when we look into the details, we are struck by the difference in the remuneration of persons apparently undergoing equal toils, and exercising equal abstinence. We find a general exempt from more than half the hardships of a private, and receiving more than a hundred times his pay. We find barristers making £10,000 or £15,000 a year, while a copying clerk is paid for labour as assiduous and more irksome by only £100. We find the purchaser of an Exchequer-bill willing to pay a large premium for the privilege of advancing capital at a profit of three per cent. per annum, while a shopkeeper thinks himself ill paid by less than twenty per cent. We find a London banker satisfied with a profit of seven per cent., while his partner in Calcutta requires fifteen.

These differences are partly real and partly apparent. So far as they are real, they are occasioned partly by the influence of the different instruments of production, or, in other words, the different sources of revenue, on one another; the influence, for instance, of the rate of profits on

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the amount of wages, and of the amount of wages on the rate of profits; partly by the greater or less severity of the sacrifices which the labourer and the capitalist must make in addition to the undergoing mere toil or abstinence; and partly by the difficulty with which capital and labour are transferred from one employment to another. A difficulty caused partly by physical obstacles and partly by human habits and institutions. The influence of these causes on the average rates of wages and of profits in the same Country, in different employments of labour and capital, we shall consider hereafter; and having assumed for the purposes of the following discussion that a certain average rate of wages and a certain average rate of profit exists, we shall now endeavour to explain the causes by which these average rates are determined, or, in other words, to explain *the circumstances which decide what, at a given time and in a given place, shall be the average rate of wages and the average rate of profit.* We have already stated as one of the principal sources of difficulty in Political Economy the mutual dependence of its different propositions. A dependence which, as it respects the theory of wages and profits, is so great that it is impossible to give a complete view of the causes which affect the one without adverting to all those which affect the other. We shall endeavour to keep them as distinct as we can, and we shall begin by wages, as that subject is capable of being separately considered to the greatest extent.

Rate of wages.

Average Rate of Wages.

Meanings of the adjectives *high* and *low*, as applied to wages.

We have already defined wages to be the remuneration received by the labourer in recompense for having exerted his faculties of mind and body. They are said to be *high* or *low*, in proportion to the extent of that remuneration. That extent has been estimated by three different measures; and the words high and low wages have, consequently, been used in three different senses.

First. Wages have been termed high or low, according to the amount of *money* earned by the labourer within a given period, without any reference to the commodities which that money would purchase; as when we say that wages have *risen* in England since the reign of Henry VII., because the labourer now receives 1*s*. 6*d*. or 2*s*. a day, and then received only 4½*d*.

Secondly. They have been termed high or low, according to the *quantity and quality of the commodities* obtained by the labourer, without any reference to his receipts in money; as when we say that wages have *fallen* in England since the reign of Henry VII., because the labourer then earned two pecks of wheat a day, and now earns only one.

Thirdly. They have been termed high or low, according to the share or proportion which the labourer receives of the produce of his own labour, without any reference to the total amount of that produce.

The first nomenclature, that which measures wages simply by their amount in money, is the popular one. The second, that which considers wages simply with reference to the quantity and quality of the commodities received by the labourer, or, to speak more correctly, purchasable with his money wages, was that generally adopted by Adam Smith. The third, that which considers wages as high or low, simply with reference to the labourer's share or proportion of what he produces, was introduced by Mr. Ricardo, and has been continued by many of his followers.

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This last use of the words high and low wages has always appeared to us one of the most unfortunate of Mr. Ricardo's many innovations in the language of Political Economy. In the first place, it has a tendency to withdraw our attention, even when we are considering the subject of wages, from the facts which most influence the labourer's condition. To ascertain whether his wages are high or low, we are desired to inquire, not whether he is ill or well paid,—not whether he is well or ill fed, or clothed, or lodged, or warmed, but simply what proportion of what he produces comes to his share. During the last four or five years many a hand-weaver has received only 8*s*. 3*d*. for producing, by a fortnight's exertion, a web that the capitalist has sold for 8*s*. 4*d*. A coal-merchant often pays his men £2 a week, and charges his employers for their services £2 10*s*. But, according to Mr. Ricardo's nomenclature, the wages of the weaver, at 4*s*. 1½*d*. a week, are much higher than those of the coalheaver at £2, since the weaver receives 99 per cent. of the value of his labour, while the coalheaver has only 80 per cent.

And, even if the nomenclature in question were free from this objection, even if the point on which it endeavours to fix the attention were the most important, instead of being the least important, incident to wages, it still would be inconvenient from its tendency to render the writer who employs it both inconsistent and obscure. It is almost impossible to affix to terms of familiar use a perfectly new meaning, and not from time to time to slide into the old one. When Mr. Ricardo says that "nothing can affect profits but a rise of wages," p. 118; that "whatever raises the wages of labour lowers the profits of stock," p. 231; that "high wages invariably affect the employers of labour by depriving them of a portion of their real profits," p. 129; that "as the wages of labour fall the profits of stock rise," p. 499; he means by high wages, not a large *amount*, but a large *proportion*. But when he speaks of the "encouragement which high wages give to the increase of population," p. 88—361, he means by high wages a large *amount*. And many of his followers and opponents have supposed the words high and low to be used by him as indicative of quantity, not proportion. The consequence has been that, since the publication of his great Work, an opinion has prevailed that high wages and high profits are incompatible, and that whatever is taken from the one is added to the other. The slightest attempt to try this theory by an actual example will show its absurdity. The usual supposition is, that the capitalist, at an average, advances the wages of his labourers for one year, and receives, after deducting rent, one-tenth of the value of what they produce. We are inclined to think that in England the average rate of profit is rather greater, and the average period of advance rather less. After making many inquiries on these subjects in Manchester, we found the general opinion to be, that the manufacturing capitalist turns his capital, at an average, twice in the year, and receives on each operation a profit of 5 per cent.; and that the shopkeeper, at an average, turns his capital four times in a year, and receives on each operation a profit of about 3½ per cent. On these data the labourer's share would, of course, be much greater than according to the ordinary estimate. We will suppose, however, that estimate to be correct, and that, after rent has been deducted, the labourer receives, on an average, nine-tenths of the value of what he produces. Under these circumstances a rise in the amount

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of wages amounting to one-tenth, or from 10*s.* to 11*s.* a week, if that rise is to be deducted from the capitalist's share, would utterly destroy all profit whatever. A rise of one-fifth, or from 10*s.* to 12*s.* a week, would occasion to the capitalist a loss equal to the whole amount of his former profit. A fall in wages of one-tenth would double profits; a fall of one-fifth would treble them. Now we know that general variations in the amount of wages to the amount of one-tenth or one-fifth, or to a greater extent, are not of unfrequent occurrence. Yet who ever heard of their producing such an effect on profits?

And yet this doctrine has received the sanction both of theoretic and practical men. Mr. Francis Place is asked by the Committee on Artisans and Machinery (First Report, p. 46,*) "Do not the masters in consequence of a rise of wages raise their prices?"—"No," he answers; "I believe there is no principle of Political Economy better established than this of wages; increase of wages must come from profits."

Did Mr. Place ever apply this doctrine when his men asked for higher wages on a general mourning? Even the Committee appear to have taken this view of the question. The subject is so important, that we will venture to extract the following passage from the Report made in the following Session:—

"Those eminent persons who, during the last fifty years, have reduced the rules that govern the operations of trade and industry to a Science, undertake to show, by arguments and facts, that the effect of low wages is not a low price of the commodity to which they are applied, but the raising of the average rate of profits in the Country in which they exist. The explanation of this proposition occupies a large portion of the justly-celebrated work of the late Mr. Ricardo, on the Principles of Political Economy; and is also ably set forth in the following evidence of Mr. M'Culloch, to which your Committee particularly desire to draw the attention of the House:

"'Have you turned your attention to the effect of fluctuations in the rate of wages on the price of commodities?'—'I have.'

"'Do you consider that when wages rise the price of commodities will proportionally increase?'—'I do not think that a real rise of wages has any effect whatever, or but a very imperceptible one, on the price of commodities.'

"'Then, supposing wages to be really lower in France than in this Country, do you think that that circumstance would give the French any advantage over us in the foreign market?'—'No, I do not; I do not think it would give them any advantage whatever. I think it would occasion a different distribution of the produce of industry in France from what would obtain in England, but that would be all. In France the labourers would get a less proportion of the produce of industry, and the capitalists a larger proportion.'

"'Could not the French manufacturer, if he gets his labour for less than the English manufacturer, afford to sell his goods for less?'—'As the value of goods is made up wholly of labour and profit, the whole and only effect of a French manufacturer getting his labour for less than an English manufacturer is to enable him to make more profit than the English manufacturer can make, but not to lower the price of his goods. The low rate of wages in France goes to establish a high rate of profits in all branches of industry in France.'

* Session of 1824.

"'What conclusion do you come to in making a comparison between wages in England and wages in France?'—'I come to this conclusion, that, if it be true that wages are really higher in England than in France, the only effect of that would be to lower the profits of capital in England below their level in France, but that will have no effect whatever on the price of the commodities produced in either Country.'

"'When you say that wages do not affect prices, what is it that does affect prices?'—'An increase or diminution of the quantity of labour necessary to the production of the commodity.'

"'Supposing that there was a free export of machinery, so that France could get that machinery, do you think that under those circumstances we should retain those advantages which we possess at the present moment?'—'Yes, we should; for the export of the machinery would not lower our wages, or increase the wages in France, so that we should preserve that advantage to the full extent that we have it at this moment.'

"'Will you explain to the Committee why you are of opinion that the French manufacturer would not undersell the English, seeing that his profits are larger than the English manufacturer?'—'Because, if he were to offer to undersell the English, he can only do it by consenting to accept a less rate of profit on his capital than the other French capitalists are making on theirs, and I cannot suppose a man of common sense would act upon such a principle.'

"'Are the Committee to understand, that although a French manufacturer pays half the wages to his men in France which our manufacturers do in England, yet that his wages being on a par, or a level, in general, with the other wages in France, will render his profits on a par with them, and consequently he would not undersell the English merchant by lowering his profits below the average rate of profits in France?'—'Precisely so. I believe, in point of fact, there is no such difference; but he could not undersell the English manufacturer unless he took lower profits than all other producers in France were making. I might illustrate this by what takes place every day in England, where you never find the proprietor of rich land, in order to get rid of his produce, offering it in Mark-lane at a lower rate than that which is got by a farmer or proprietor of the very worst land in the Kingdom.'

"'Would it not produce a larger sale if the French manufacturer were to sell at a less price?'—'Supposing that to be so, the greater the sale the greater would be the loss of profit.'"*

We have extracted this passage as indicating the views of the Committee, not those of Mr. M'Culloch. Mr. M'Culloch, as will appear on turning to his evidence, meant by wages *really high* and *really low*, not a larger or a smaller amount, but a larger or a smaller proportion. But the Committee appear to have understood him to mean a larger or a smaller amount.

Mr. Bradbury had previously stated the common day wages in France to be about half the wages paid in England.

He was asked, "In what way do you consider that lower wages in France give the French manufacturers an advantage over English manufacturers?"—"I conceive that if they pay 3*d.* a pound for spinning to the

* Report from Select Committee on Export of Tools and Machinery. Session of 1825, p. 13, 14.

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operative spinner, and we pay 6*d*., that would give them an advantage of 3*d*. a pound in the cost."

"You mean to say that the French would be able to sell the article they make, in consequence of paying lower wages, cheaper than the English could sell it?"—"They could afford it 3*d*. a pound cheaper."

"You mean to say that, according to the rate of wages paid, the price of the article for which they are paid is high or low?"—"It may be afforded higher or lower, I should imagine, as the cost be more or less."

"Therefore the whole reason and ground on which you think that low wages give them an advantage is, that low wages contribute to enable them to sell the article cheaper than if they paid higher wages?"—"Yes, labour constituting a material feature in the cost."

"You conceive that increased cost would be a loss to the party, if the price was not increased in proportion?"—"I should imagine so."

"*Might not the profits of the proprietor be lessened?*"—"*They might be lessened, which is in effect a loss.*"

"*Might not that enable him to bear the loss which the difference of wages produces?*" *—"*If he chose to make that sacrifice.*"

"Might not the profits be lessened until there were no profits at all!"†—"Very easily, I should think."—(Fifth Report of the Select Committee on Artisans and Machinery, p. 547, 549, 550.)

It was with reference to this evidence that Mr. M'Culloch was examined. His examination commences thus:

"Have you read the evidence which has been given before this Committee?"—"I have read portions of it only."

"Have you read the evidence given by Mr. Bradbury?"—"A part of it."

"That part in which he conceives that foreigners have an advantage over the English manufacturers in consequence of wages being lower in France?"—"Yes, I have read that."

And then follows the question:

"Have you turned your attention to the effect of fluctuations in the rate of wages on the price of commodities?"

Now if the Committee understood Mr. M'Culloch to mean, by high or low wages, not a great or small amount, but a great or small proportion, his evidence and that of Mr. Bradbury had nothing in common.

The whole of the confusion has been occasioned by the verbal ambiguity which we have pointed out, and would not have arisen if Mr. Ricardo had used any other adjectives than *high* and *low* to express a larger or smaller proportion.

The two other meanings of the words high and low wages, that which refers to the money, and that which refers to the commodities, received by the labourer, are both equally convenient, if we consider the rate of wages *at the same time and place;* for then they both mean the same thing. At the same time and place the labourer who receives the highest wages necessarily obtains the most commodities. But when we refer to different places, or different times, the words high or low wages direct the attention to very different subjects, as we understand them to mean more or less in money, or more or less in commodities. The differences which have taken place in the amount of money wages at different times inform us of scarcely any thing but the abundance or scarcity of the precious metals at those times: facts which are seldom of much importance. The differences in the amount of money wages in different places at the same time are of much more importance, since they indicate the different values of the labour of different Countries in the general market of the world. But even these differences afford no premises from which the positive condition of the labouring classes, in any Country, can be inferred, and but imperfect grounds for estimating their relative condition. The only data which enable us to ascertain the actual situation of the labourers at any given time and place, or their comparative situation at different times and places, are the quantity and quality of the commodities which form their wages, if paid in kind, or are purchasable with their wages, if paid in money. And as the actual or comparative situation of the labourer is the principal object of the following inquiry, we shall use the word wages to express, not the money, but the commodities, which the labourer receives; and we shall consider wages to rise as the quantity or quality of those commodities is increased or improved, and to fall as that quantity or quality is diminished or deteriorated.

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It is obvious, too, that the labourer's situation does not depend on the amount which he receives at any one time, but on his average receipts during a given period—during a week, a month, or a year; and that the longer the period taken, the more accurate will be the estimate. Weekly wages have, of course, more tendency to equality than daily ones, and annual than monthly; and, if we could ascertain the amount earned by a man during five, or ten, or twenty years, we should know his situation better than if we confined our attention to a single year. There is, however, so much difficulty in ascertaining the amount of wages during very long periods, that a single year will probably be the best that we can take. It comprehends what, in most climates, are very different, summer and winter wages; it comprehends also the period during which the most important vegetable productions come to maturity in temperate climates, and on that account has generally been adopted by Political Economists as the average period for which capital is supposed to be advanced.

We should observe that we include, as part of the wages of the married labourer, those of his wife and unemancipated children. To omit them would lead to inaccurate estimates of the comparative situation of the labourers in different Countries, or in different occupations. In those employments which are carried on under shelter, and with the assistance of that machinery which affords power, and requires human aid only for its direction, the industry of a woman, or a child, approaches in efficiency that of a full-grown man. A girl of fourteen can manage a power-loom nearly as

* In other words, "Might not the loss enable him to bear the loss?"

† This question appears to have come from a different interrogator. In justice to the clear and intelligent evidence of Mr. Bradbury, we should observe that he was far from falling into the common error, that a generally high rate of wages can be unfavourable to a Country. He set out by supposing that, with the assistance of English machinery and English superintendents, the labour of the French spinners might be as productive as that of the English spinners. Under such circumstances, if their wages could remain at one-half of English wages, he believed that the French manufacturer could undersell the English manufacturer. Of the accuracy of this opinion under the possible, though highly improbable hypothesis in question, we entertain no doubt, though, from the tenour of the questions, it appears not to have met with the approbation of the Committee.

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well as her father; but where strength, or exposure to the seasons, is required, little can be done by the wife, or the girls, or even by the boys, until they approach the age at which they usually quit their father's house. The earnings of the wife and children of many a Manchester weaver or spinner exceed, or equal, those of himself. Those of the wife and children of an agricultural labourer, or of a carpenter, or a coalheaver, are generally unimportant—while the husbands, in each case, receives 15*s.* a week, the weekly income of the one family may be 40*s.*, and that of the other only 17*s.* or 18*s.*

It must be admitted, however, that the workman does not retain the whole of this apparent pecuniary advantage. The wife is taken from her household labours, and a part of the increased wages is employed in purchasing what might, otherwise, be produced at home. The evils to the children are still greater. The infants suffer from the want of maternal attention, and those who are older from fatigue and confinement, from the want of childish relaxation and amusement, and, what is far more important, from the deficiency of religious, moral, and intellectual education. The establishment of infant and Sunday schools, and laws regulating the number of hours during which children may labour, are palliatives of these evils, but they must exist, to a certain degree, whenever the labour of the wife and children is the subject of sale; and, though not, all of them, perhaps, strictly within the province of Political Economy, must never be omitted in any estimate of the causes affecting the welfare of the labouring classes.

The last preliminary point to which we have to call the reader's attention is, the difference between the *amount of wages* and the *price of labour*, or, in other words, between the earnings of a labourer during a given time and the price paid for the performance of a given quantity of work.

If men were the only labourers, and if every man worked equally hard, and for the same number of hours, during the year, these two expressions would be synonymous. If each man, for instance, worked three hundred days during each year, and ten hours during each day, one three-thousandth part of each man's yearly wages would be the price of an hour's labour. But neither of these propositions is true. The yearly wages of a family often include, as we have seen, the results of the labour of the wife and children. And few things are less uniform than the number of working days during the year, or of working hours during the day, or the degree of exertion undergone during those hours.

The established annual holidays in Protestant Countries are between fifty and sixty. In many Catholic Countries they exceed one hundred. Among the Hindoos they are said to occupy nearly half the year. But these holidays are confined to a certain portion of the population; the labour of a sailor, or a soldier, or a menial servant, admits of scarcely any distinction of days.

Again, in Northern and Southern latitudes, the hours of out-door labour are limited by the duration of light; and in all climates by the weather. When the labourer works under shelter, the daily hours of labour may be uniform throughout the year. And, independently of natural causes, the daily hours of labour vary in different Countries, and in different employments in the same Country. The daily hours of labour are, perhaps, longer in France than in England, and certainly are longer in England than in Hindostan. In Manchester the manufacturer generally works twelve hours a day; in Birmingham, ten: a London shopman is seldom employed more than eight or nine.

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There is still more discrepancy between the exertions made by different labourers in a given period. They are often, indeed, unsusceptible of comparison. There is no common measure of the toils undergone by a miner and a tailor, or of those of a shopman and an iron-founder. And labour which is the same in kind may vary indefinitely both in intensity and in productiveness. Many of the witnesses examined by the Committee on Artisans and Machinery (Session of 1824) were English manufacturers, who had worked in France. They agree as to the comparative indolence and inefficiency of the French labourer, even during his hours of employment. One of the witnesses, Adam Young, had been two years in one of the best manufactories in Alsace. He is asked, "Did you find the spinners there as industrious as the spinners in England?" and replies, "No; a spinner in England will do twice as much as a Frenchman. They get up at four in the morning, and work till ten at night; but our spinners will do as much in six hours as they will in ten."

"Had you any Frenchmen employed under you?"—"Yes; eight, at two francs a day."

"What had you a day?"—"Twelve francs."

"Supposing you had had eight English carders under you how much more work could you have done?"—"With one Englishman I could have done more than I did with those eight Frenchmen. It cannot be called work they do: it is only looking at it, and wishing it done."

"Do the French make their yarn at a greater expense?"—"Yes; though they have their hands for much less wages than in England."—pp. 580, 582.

The following evidence of Edwin Rose, given on the Factory Inquiry of 1833, relates to a rather later period, and is valuable from the extensive experience of the witness.

"Are wages lower in France, as far as you have seen, than in England?"—"If I have a shop of men in England for any thing, then I have to see how much I have to pay them for the work they turn out of any kind; but if I have the same shop in France, then I must have twice the number of hands to do the same amount of work. It is true I pay them less apiece there; but I have seen that you must have twice as large a building to contain the hands, twice as many clerks and book-keepers, and overlookers to look after them, and twice as many tools to do the same quantity of work as is done here in England; and the master there must have twice as much interest of money on all this; and their minds seem to me to get more bewildered with stress of work there than here. It seems to me that you have double the number of people there to do the same amount of work, whatever it be; but their wages are lower in money."

"But do you consider their wages higher in reality?"—"I really do; they are better paid in proportion to the work they turn out than what the English are."

"What do you think of French workmen, as workmen?"—"I don't think they have that perseverance that English have. I often have noticed them trying a thing, and then, if it don't answer at first, they seem terrified and shrug up their shoulders, and throw it aside; but an English workman keeps trying and trying, and won't give up near so soon as the Frenchman. A house-

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joiner or carpenter's wages are from thirty-five to forty sous a day. His work compared with English work is very rough, and but little of it in comparison. A stone-mason's wages are from three francs to four francs. They are inferior to our masons in laying foundations. Then, as to time of work, I think two English masons in the same time do more work on an average than three of theirs."

"In short, do you know any single species of labour that stands a master cheaper in France than in England, quality and quantity of work being considered?"—"I don't know any, unless it be tailors and shoemakers' wages; and I am not sure about them. Clothes are dearer in France than in England; but shoes are cheaper, the duty being off leather." *First Report of the Factory Commission*, D. i. p. 121.

Even in the same Country, and in the same employments, similar inequalities are constantly observed. Every one is aware that much more exertion is undergone by the labourer by task-work than by the day-labourer; by the independent day-labourer than by the pauper; and even by the pauper than by the convict.

It is obvious that the rate of wages is less likely to be uniform than the price of labour, as the amount of wages will be affected, in the first place, by any variations in the price, and, in the second place, by any variations in the amount, of the labour exerted.

In England the average annual wages of labour are three times as high as they are in Ireland; but as the labourer in Ireland is said not to do more than one-third of what is done by the labourer in England, the price of labour may, in both Countries, be about equal. In England the labourer by task-work earns much more than the day-labourer; but, as it is certainly as profitable to employ him, the price of his labour cannot be higher. It may be supposed, indeed, that the price of labour is every where, and at all times, the same; and, if there were no disturbing causes,—if all persons knew perfectly well their own interest, and strictly followed it, and there were no difficulties in moving capital and labour from place to place, and from employment to employment,—the price of labour, at the same time, would be every where the same. But these difficulties occasion the price of labour to vary materially, even at the same time and place; and variations both in the amount of wages and in the price of labour, at different times and in different places, are occasioned not only by these causes, but by others which will be considered in a subsequent part of this Treatise.

These variations affect very differently the labourer and his employer. The employer is interested in keeping down the price of labour; but while that price remains the same, while at a given expense he gets a given amount of work done, his situation remains unaltered. If a farmer can get a field trenched for £12, it is indifferent to him whether he pays the whole of that sum to three capital workmen, or to four ordinary ones. The three would receive higher wages than the four, but, as they would do proportionably more work, their labour would come just as cheap. If the three could be hired at £3 10*s*. apiece, while the four required £3 apiece, though the wages of the three would be higher, the price of the work done by them would be lower.

It is true that the causes which raise the amount of the labourer's wages often raise the rate of the capitalist's profits. If, by increased industry, one man performs the work of two, both the amount of wages and the rate of profits will generally be raised. But the rate of profit will be raised, not by the rise of wages, but in consequence of the additional supply of labour having diminished its price, or having diminished the period for which it had previously been necessary to advance that price, or having rendered, as in the instances mentioned by Edwin Rose, the labour previously employed more productive.

The labourer, on the other hand, is principally interested in the amount of wages. The amount of his wages being fixed, it is certainly his interest that the price of his labour should be high, for on that depends the degree of exertion imposed on him. But, if the amount of his wages be low, he must be comparatively poor—if that amount be high he must be comparatively rich—whatever be his remuneration for each specific act of exertion. In the one case he will have leisure and want; in the other toil and abundance. We are far from thinking that the evils of severe and incessant labour, or the benefits of a certain degree of leisure, ought to be left out in any estimate of happiness. But, as we observed in the beginning of this Treatise, it is not with happiness, but with wealth, that we are concerned as Political Economists; we profess to state facts for the information and instruction of the student, not to lay down rules to guide the conduct of the legislator. In explaining the general laws according to which wealth is produced and distributed we do not assume that all the means by which it can be augmented ought to be encouraged, or even to be permitted. We do not assume even that wealth is a benefit. In fact, however, wealth and happiness are very seldom opposed. Nature, when she imposed on man the necessity of labour, tempered his repugnance to it by making long-continued inactivity painful, and by strongly associating with exertion the idea of its reward. The poor and half-employed Irish labourer, or the still poorer and less industrious savage, is as inferior in happiness as he is in income to the hard-worked English artisan. The Englishman's industry may sometimes be excessive; his desire to better his condition may sometimes drive him on toils productive of disease ill recompensed by the increase of his wages; but that such is not generally the case may be proved by comparing the present duration of life in England with its former duration, or with its duration in other Countries. It is generally admitted that, during the last fifty years, a marked increase has taken place in the industry of our population, and that they are now the hardest-working labourers in the world. But during the whole of that period the average duration of their lives has been constantly increasing, and appears still to increase; and, notwithstanding the apparent unhealthiness of many of their occupations, notwithstanding the atmosphere of smoke and steam, and, what appears to be still more injurious, of dust, in which many of them labour for sixty-nine hours a week, they enjoy, as a community, longer life than the lightly-toiled inhabitants of the most favoured soils and climates.

The average annual mortality in England and Wales is computed by Mr. Rickman at one in forty-nine. In the extensive inquiry instituted by the Poor-Law Commissioners in 1834 into the state of the labouring classes in America and the Continent of Europe, the only Countries in which the mortality appeared to be so small as in England were Norway, in which it appeared to be one in fifty-four, and the Basses Pyrenees, in which it appeared to be one in fifty. In all the other Countries

which gave returns it exceeded the English proportion sometimes by doubling it, and in the majority of instances by more than one-fourth.*

Having marked the distinction which really exists between the price of labour and the amount of wages, we shall for the future consider every labouring family as consisting of the same number of persons, and exerting the same degree of industry. On that supposition, the distinction between the price of labour and the amount of wages will be at an end; or rather, the only distinction will be, that the former expression designates the remuneration for each specific exertion; the latter, the aggregate of all those separate remunerations, as summed up at the end of each year. And the question to be answered will be, what are the causes which decide what in any given Country, and at any given period, shall be the quantity and quality of the commodities obtained by a labouring family during a year?

Proximate Cause deciding the Rate of Wages.

The proximate cause appears to be clear. The quantity and quality of the commodities obtained by each labouring family during a year must depend on the quantity and quality of the commodities directly or indirectly appropriated during the year to the use of the labouring population, compared with the number of labouring families, (including under that term all those who depend on their own labour for subsistence;) or, to speak more concisely, on the extent of the fund for the maintenance of labourers, compared with the number of labourers to be maintained.

This proposition is so nearly self-evident, that if Political Economy were a new Science we should assume it without further remark. But we must warn our readers that this proposition is inconsistent with opinions which are entitled to consideration, some from the number, and others from the authority, of those who maintain them.

Erroneous Opinions.

First. It is inconsistent with *the doctrine that the rate of wages depends solely on the proportion which the number of labourers bears to the amount of Capital in a Country.* The word capital has been used in so many senses that it is difficult to state this doctrine precisely; but we know of no definition of that term which will not include many things that are not used by the labouring classes; and, if our proposition be correct, no increase or diminution of *these* things can *directly* affect wages. If half the plate glass in the Country were to be destroyed to-morrow the capital of the Country would be diminished; but the only sufferers would be those who possess or wish to possess plate glass; among whom the labouring classes are not included. But if half the existing stock of coarse tobacco were destroyed, the immediate consequence would be a fall of wages; not as estimated in money, but as estimated in the commodities consumed by the labourer. Though receiving the same money wages, the labourer would have less tobacco, or, if he chose to continue undiminished his consumption of tobacco, then less of other things, than he had before. So if a foreign merchant were to come to settle in this Country, and bring with him a cargo of raw and manufactured silk, lace, and diamonds, that cargo would increase the capital of the Country; silk, lace, and diamonds would become more abundant, and the enjoyments of those who use them would be increased: the enjoyments of the labourers, supposing them not to be consumers of silk, lace, or diamonds, would not be directly increased: indirectly and consequentially, they might be increased. The silk might be re-exported in a manufactured state, and commodities for the use of labourers imported in return; and then, and not till then, wages would rise; but that rise would be occasioned, not by the first addition to the capital of the Country, which was made in the form of silk, but by the substituted addition made in the form of commodities used by the labourer.

Secondly. It is inconsistent with *the doctrine, that wages depend on the proportion borne by the number of labourers to the whole revenue of the society of which they are members.* In the example last suggested, of the introduction of a new supply of lace or diamonds, the *revenues* of those who use lace or diamonds would be increased; but as wages are not spent on those articles, *they* would remain unaltered. It is possible, indeed, to state cases in which the revenue of a large portion of a community might be increased, and yet the wages of the labourers might fall without an increase of their numbers. We will suppose the principal trade of Ireland to be the raising produce for the English market; and that for every two hundred acres ten families were employed in raising, on half the land, their own subsistence, and on the remainder corn and other exportable crops requiring equal labour. Under such circumstances, if a demand should arise in the English market for cattle, butchers'-meat, and wool, instead of corn, it would be the interest of the Irish landlords and farmers to convert their estates from arable into pasture. Instead of ten families for every two hundred acres, two might be sufficient: one to raise the subsistence of the two, and the other to tend the cattle and sheep. The revenue of the landlords and the farmers would be increased: and, if they employed the whole of that increase in the purchase of Irish labour, all parties would be benefited. But if they devoted the greater part of it to the purchase of English manufactures, the services of a large portion of the Irish labourers would cease to be required; a large portion of the land formerly employed in producing commodities for their use would be devoted to the production of commodities for the use of England; and the fund for the maintenance of Irish labour would fall, notwithstanding the increase of the revenue of the landlords and farmers.

Absenteeism.

Thirdly. It is inconsistent with *the prevalent opinion, that the non-residence of landlords, funded proprietors, mortgagees, and other unproductive consumers, can be detrimental to the labouring inhabitants of a Country which does not export raw produce.*

In a Country *which exports raw produce*, wages *may* be lowered by such non-residence. If an Irish landlord resides on his estate, he requires the services of certain persons, who must also be resident there, to minister to his daily wants. He must have servants, gardeners, and perhaps gamekeepers. If he build a house, he must employ resident masons and carpenters; part of his furniture he may import, but the greater part of it must be made in his neighbourhood; a portion of his land, or, what comes to the same thing, a portion of his rent, must be employed in producing food, clothing, and shelter for all these persons, and for those who produce that food, clothing, and shelter. If he were to remove to England, all these wants would be supplied by Eng-

* Senior, *Preface to Foreign Communications*, p. 238.

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lishmen. The land and capital which was formerly employed in providing the maintenance of Irish labourers would be employed in producing corn and cattle to be exported to England to provide the subsistence of English labourers. The whole quantity of commodities appropriated to the use of Irish labourers would be diminished, and that appropriated to the use of English labourers increased, and wages would, consequently, rise in England, and fall in Ireland.

It is true that these effects would not be co-extensive with the landlord's income. While, in Ireland, he must have consumed many foreign commodities, he must have purchased tea, wine, and sugar, and other things which the climate and the manufactures of Ireland do not afford, and he must have paid for them by sending corn and cattle to England. It is true, also, that while in Ireland he probably employed a portion of his land and of his rents for other purposes, from which the labouring population received no benefit, as a deer park, or a pleasure garden, or in the maintenance of horses or hounds. On his removal, that portion of his land which was a park would be employed, partly in producing exportable commodities, and partly in producing subsistence for its cultivators; and that portion which fed horses for his use might be employed in feeding horses for exportation. The first of these alterations would do good; the second could do no harm. Nor must we forget that, through the cheapness of conveyance between England and Ireland, a portion, or perhaps all, of those whom he employed in Ireland might follow him to England, and, in that case, wages in neither Country would be affected. The fund for the maintenance of labourers in Ireland, and the number of labourers to be maintained, would both be equally diminished, and the fund for the maintenance of labourers in England, and the number of labourers to be maintained, would both be equally increased.

But after making all these deductions, and they are very great, from the supposed effect of the absenteeism of the Irish proprietors on the labouring classes in Ireland, we cannot agree with Mr. M'Culloch that it is immaterial. We cannot but join in the general opinion that their return, though it would not affect the prosperity of the British Empire, considered as a whole, would be immediately beneficial to Ireland, though perhaps too much importance is attached to it.

In Mr. M'Culloch's celebrated examination before the Committee on the state of Ireland, (4th Report, 814, Sess. 1825.) he was asked, " Supposing the largest export of Ireland were in live cattle, and that a considerable portion of rent had been remitted in that manner, does not such a mode of producing the means of paying rent contribute less to the improvement of the poor than any extensive employment of them in labour would produce?— He replies, " Unless the means of paying rent are changed when the landlord goes home, his residence can have no effect whatever."

" Would not," he is asked, " the population of the country be benefited by the expenditure among them of a certain portion of the rent which (if he had been absent) has (would have) been remitted (to England)?" " No," he replies, " I do not see how it could be benefited in the least. If you have a certain value laid out against Irish commodities in the one case, you will have a certain value laid out against them in the other. The cattle are either exported to England, or they stay at home. If they are exported, the landlord will obtain an equivalent for them in English commodities; if they are not, he will obtain an equivalent for them in Irish commodities; so that in both cases the landlord lives on the cattle, or on the value of the cattle: and whether he lives in Ireland or in England, there is obviously just the very same amount of commodities for the people of Ireland to subsist upon."

This reasoning assumes that the landlord, while resident in Ireland, himself personally devours all the cattle produced on his estates; for on no other supposition can there be the very same amount of commodities for the people of Ireland to subsist upon, whether their cattle are retained in Ireland or exported.

But when a Country does *not* export raw produce, the consequences of absenteeism are very different. Those who derive their incomes from such a Country cannot possibly spend them abroad until they have previously spent them at home.

When a Leicestershire landlord is resident on his estate, he employs a certain portion of his land, or, what is the same, of his rent, in maintaining the persons who provide for him those commodities and services, which must be produced on the spot where they are consumed. If he should remove to London, he would want the services of Londoners, and the produce of land and capital which previously maintained labourers resident in Leicester would be sent away to maintain labourers resident in London. The labourers would probably follow, and wages in Leicestershire and London would *then* be unaltered; but until they did so, wages would rise in the one district and fall in the other. At the same time, as the rise and fall would compensate one another, as the fund for the maintenance of labour, and the number of labourers to be maintained, would each remain the same, the same amount of wages would be distributed among the same number of persons, though not precisely in the same proportion as before.

If he were now to remove to Paris, a new distribution must take place. As the price of raw produce is lower in France than in England, and the difference in habits and language between the two Countries prevents the transfer of labourers from the one to the other, neither the labourers nor the produce of his estates could follow him. He must employ French labourers, and he must convert his share of the produce of his estate, or, what is the same thing, his rent, into some exportable form in order to receive it abroad. It may be supposed that he would receive his rent in money. Even if he were to do so, the English labourers would not be injured, for as they do not eat or drink money, provided the same amount of commodities remained for their use, they would be unaffected by the export of money. But it is impossible that he could receive his rent in money unless he chose to suffer a gratuitous loss. The rate of exchange between London and Paris is generally rather in favour of London, and scarcely ever so deviates from par between any two Countries, as to cover the expense of transferring the precious metals from the one to the other, excepting between the Countries which do, and those which do not, possess mines. The remittances from England to France must be sent, therefore, in the form of manufactures, either directly to France, or to some Country with which France has commercial relations. And how would these manufactures be obtained? Of course in exchange for the landlord's rent. His share of the produce of his estates would now go to Birmingham or Sheffield, or Manchester or London, to main-

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tain the labourers employed in producing manufactures, to be sent and sold abroad for his profit. An English absentee employs his income precisely as if he were to remain at home and consume nothing but hardware and cottons. Instead of the services of gardeners and servants, upholsterers and tailors, he purchases those of spinners, and weavers, and cutlers. In either case his income is employed in maintaining labourers, though the class of labourers is different; and in either case, the whole fund for the maintenance of labourers, and the number of labourers to be maintained, remaining unaltered, the wages of labour cannot be affected.

But, in fact, that fund would be rather increased in quantity and rather improved in quality. It would be increased, because land previously employed as a park, or in feeding dogs and horses, or hares and pheasants, would now be employed in producing food or clothing for men. It would be improved, because the increased production of manufactured commodities would occasion an increased division of labour, the use of more and better machinery, and the other improvements which we have ascertained to be its necessary accompaniments.

One disadvantage, and one only, it appears to us would be the result. The absentee in a great measure escapes domestic taxation. We say *in a great measure*, because he still remains liable, if a proprietor of houses or of land, to those taxes which fall upon rent: he pays, too, a part of the taxes on the materials of manufactures; and if it were our policy to tax income or exported commodities, he might be forced to pay to the public revenue even more than his former proportion. But, under our present system, which throws the bulk of taxation on commodities produced for internal consumption, he receives the greater part of his revenue without deduction, and, instead of contributing to the support of the British Government, contributes to support that of France or Italy. This inconvenience, perhaps, about balances the advantages which we have just mentioned, and leaves a community which exports only manufactures neither impoverished nor enriched by the residence abroad of its unproductive members.

We ought, perhaps, on this occasion again to remind our readers that it is to wealth and poverty that our attention, when writing on Political Economy, is confined. The *moral* effects of absenteeism must never be neglected by a writer who inquires into the causes which promote the *happiness* of nations, but are without the province of a Political Economist. Nor do we regret that they are so, for they form a subject on which it is far more difficult to obtain satisfactory results. In one respect, indeed, the moral question is the more simple, as it is not complicated by the consideration whether raw produce or manufactures are exported, or whether the non-resident landlord is abroad, or in some town within his own Country. If his presence is to be morally beneficial, it must be his presence on his own estate. To the inhabitants of that estate the place to which he absents himself is indifferent. Adam Smith believed his residence to be morally injurious. "The residence of a Court," he observes. (book ii. ch. iii.) "in general makes the inferior sort of people dissolute and poor. The inhabitants of a large village, after having made considerable progress in manufactures, have become idle in consequence of a great Lord having taken up his residence in their neighbourhood." And Mr. M'Culloch, whose fidelity and intelligence as an observer may be relied on, states, as the result of his own experience, that in Scotland the estates of absentees are almost always the best managed. Much, of course, depends on individual character; but we are inclined to believe that, in general, the presence of men of large fortune is morally detrimental, and that of men of moderate fortune morally beneficial, to their immediate neighbourhood. The habits of expense and indulgence which, in different gradations, prevail among all the members of a great establishment, are mischievous as examples, and perhaps still more so as sources of repining and discontent. The drawing-room and stable do harm to the neighbouring gentry, and the housekeeper's room and servants' hall to their interiors. But families of moderate income, including under that term incomes between £500 and £2000 a year, appear to be placed in the station most favourable to the acquisition of moral and intellectual excellence, and to its diffusion among their associates and dependents. We have no doubt that a well-regulated gentleman's family, removing the prejudices, soothing the quarrels, directing and stimulating the exertions, and awarding praise or blame to the conduct of the villagers round them, is among the most efficient means by which the character of a neighbourhood can be improved. It is the happiness of this Country that almost every parish has a resident fitted by fortune and education for these services; and bound, not merely by feelings of propriety, but as a matter of express and professional duty, to their performance. The dispersion throughout the Country of so many thousand clerical families, each acting in its own district as a small centre of civilization, is an advantage to which, perhaps, we have been too long accustomed to be able to appreciate its extent.

Still, however, we think that even the moral effects of absenteeism have been exaggerated. Those who declaim against the twelve thousand English families supposed to be resident abroad, seem to forget that not one-half, probably not one-quarter, of them, if they were to return, would dwell any where but in towns, where their influence would be wasted, or probably not even exerted. What does it signify to the Northumbrian or Devonshire peasant whether his landlord lives in London, or Cheltenham, or Rome? And even of those who would reside in the country, how many would exercise that influence beneficially? How many would be fox-hunters or game-preservers, or surround themselves with dependents whose example would more than compensate for the virtues of their masters? Nothing can be more rash than to predict that *good* would be the result of causes which are quite as capable of producing evil.

The economical effects have been still more generally misunderstood; and we have often been tempted to wonder that doctrines so clear as those which we have just been submitting to our readers should be admitted with reluctance even by those who feel the proofs to be unanswerable, and should be rejected at once by others, as involving a paradox too monstrous to be worth examination.

Much of this, probably, arises from a confusion of the economical with the moral part of the question. Many writers and readers of Political Economy forget that the clearest proof that absenteeism diminishes the virtue or the happiness of the remaining members of a community is no answer to arguments which aim only at proving that it does not diminish their wealth.

Another and perhaps the chief source of error is the

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circumstance that, when the landlord is present, the gain is concentrated, and the loss diffused, when he is absent the gain is diffused, and the loss concentrated. When he quits his estate, we can put our finger on the village tradesman and labourer who lose his custom and employment. We cannot trace the increase of custom and employment that is consequently scattered among millions of manufacturers. When he returns, we see that the expenditure of £2000 or £3000 a year in a small circle gives wealth and spirit to its inhabitants. We do not see, however clearly we may infer it, that so much the less is expended in Manchester, Birmingham, or Leeds. The inhabitants of his village attribute their gain and their loss to its causes; and their complaints and acknowledgments are loud in proportion to the degree in which they feel their interests to be affected. No single manufacturer is conscious that the average annual export of more than forty millions sterling has been increased or diminished to the amount of £2000 or £3000. And even if aware of that increase or diminution, he would not attribute it to the residence in Yorkshire or Paris of a given individual, of whose existence he probably is not aware. When to obvious and palpable effects nothing is to be opposed but inferences deduced by a long, though perfectly demonstrative, reasoning process, no one can doubt which will prevail, both with the uneducated, and the educated, vulgar.

Many persons, also, are perplexed by the consideration, that all the commodities which are exported as remittances of the absentee's income are exports for which no return is obtained; that they are as much lost to this Country as if they were a tribute paid to a foreign State, or even as if they were thrown periodically into the sea. This is unquestionably true; but it must be recollected, that whatever is unproductively consumed is, by the very terms of the proposition, destroyed, without producing any return. The only difference between the two cases is, that the resident landlord performs that destruction here; the absentee performs it abroad. In either case, he first purchases the services of those who produce the things which he, for his benefit, not for theirs, is to consume. If he stays here, he pays a man to brush a coat, or clean a pair of boots, or arrange a table; all which in an hour after are in their former condition. When abroad, he pays an equal sum for the production of needles, or calicoes, which are sent abroad, and equally consumed without further benefit to those who produced them. They are, in fact, sold for money to be employed in paying the wages of those foreign servants who now brush the shoes and draw the corks, which, if the landlord had not been an absentee, would have been brushed and drawn in England. The income of unproductive consumers, however paid, is a tribute; and whether they enjoy it here or elsewhere, is their own concern. We know that a man cannot eat his cake and have it; and it is equally true that he cannot sell a cake to another and keep it for himself.

Again, some acute reasoners appear to us to have been led into error on this subject, by perceiving that the income of an absentee is generally remitted to him by means of a trade in which the returns are comparatively slow,* and that the expenditure of his income is profitable to those among whom he resides.† Now assuming that these circumstances occasion a loss to any body, it is clear that the loss falls solely on the absentee. His rents are, in the first instance, expended as quickly as they are received in the purchase of manufactured commodities, to be exported for his benefit as a means of remittance. They are expended, therefore, in the support of the trade of the English manufacturer, a trade giving quick returns, high wages, and, if we may judge from the additional capital which it is attracting every day, high profits. The absentee, in thus spending his income, gives to England all that an unproductive consumer *can* give, the wages and the profits arising from the expenditure in England of his income as fast as he receives it. Neither the gain nor the loss attending on the remittance or on the subsequent expenditure of its amount are any concern of ours. They affect only the absentee. If he selects ill the place of his residence, he may have to lose by remittances at long dates, or at an unfavourable exchange, or have to pay dearly for bad commodities or unskilful services. If he selects it well, he may be a gainer by the intermediate operations to which his income has been subjected, and receive a larger revenue than he would have obtained at home, or may spend that revenue more agreeably. But with all this England has nothing to do.

The last cause to which we attribute the slow progress of correct opinions on this subject is their distastefulness to the most influential members of the community. Nothing can be more flattering to landlords, annuitants, mortgagees, and fundholders, than to be told that their residence is of vital importance to the Country. Nothing can be more humiliating than to be assured that it is utterly immaterial to the rest of the community whether they live in Brighton, or London, or Paris. Those who are aware how much our judgment, even in matters of Science, is influenced by our wishes, will not be surprised at the prejudices against a doctrine which forbids the bulk of the educated class to believe that they are benefactors to their Country by the mere act of residing within its shores.

We may appear, perhaps, to have dwelt too much on a single subject; but no prevalent error can be effectually exposed until its prevalence has been accounted for. And these are errors which are to be heard in every society, and often from those whose general views in Political Economy are correct. They may be called harmless errors, but no error is, in fact, harmless; and when there is so much in our habits that really requires alteration, we may lose sight of the real and the remediable causes of evil, while our attention is misdirected to absenteeism.

Machines.

Fourthly. Our proposition that the rate of wages depends on the extent of the fund for the maintenance of labourers, compared with the number of labourers to be maintained, is inconsistent with the *doctrine that the general rate of wages can*, except in two cases, *be diminished by the introduction of machinery.*

The two cases in which the introduction of machinery can produce such an effect are, first, when labour is employed in the *construction* of machinery, which labour would otherwise have been employed in the production of commodities for the use of labourers; and, secondly, when the machine itself consumes commodities which would otherwise have been consumed by labourers, and *that* to a greater extent than it produces them.

The first case is put by Mr. Ricardo, in his chapter on machinery; but in so detailed a form, that, instead of quoting it, we will extract its substance, with a slight

* Professor Longfield, *Lectures on Commerce and Absenteeism*, p. 6.

† Carey *on Wages*, p. 46. A Work which we regret not to have received until part of this Treatise had been stereotyped, and the remainder was in print.

variation of the terms. He supposes a capitalist to carry on the business of a manufacturer of commodities for the use of labourers; or, to use a more concise expression, the business of a manufacturer of wages. He supposes him to have been in the habit of commencing every year with a capital consisting of wages for a certain number of labourers, which we call twenty-six, and of employing that capital in hiring twenty men, to reproduce, during the year, wages for the whole twenty-six, and six to produce commodities for himself. He now supposes him to employ ten of his men during a year in producing, not wages, but a machine, which, with the aid of seven men to keep it in repair and work it, will produce every year wages for thirteen men; that is, wages for six men besides the seven that work it. At the end of the year the capitalist's situation would be unaltered: he would have wages for thirteen men, the produce of the labour of his other ten men during the year; and his machine, also the produce of the labour of ten men during the year, and therefore of equal value. And his situation would *continue* unaltered. Every year his machine would produce wages for thirteen men, of whom seven must be employed in repairing and working it, and six might, as before, be employed for the benefit of the capitalist. But we have seen that, *during the year in which the machine was constructed*, only ten men were employed in producing wages instead of twenty, and, consequently, that wages were produced for only thirteen men instead of for twenty-six. At the end of that year, therefore, the fund for the maintenance of labour was diminished, and wages must, consequently, have fallen. It is of great importance to recollect, that the only reason for this fall was the diminution of the annual production. The twenty men produced wages for twenty-six men: the machine produces wages for only thirteen. The vulgar error on this subject supposes the evil to arise, not from its true cause, the expense of constructing the machine, but from the productive powers of that machine. So far is this from being true, that those productive powers are the specific benefit which is to be set against the evil of its expensiveness. If, instead of wages for thirteen men, the machine could produce wages for thirty, its use, as soon as it came into operation, would have increased instead of diminishing the fund for the maintenance of labour. The same effect would have been produced, if the machine could have been obtained without expense; or if the capitalist, instead of building it out of his capital, had built it out of his profits; if, instead of withdrawing ten men for a year from the production of wages, he had employed in its construction, during two years, five of the men whom he is supposed to have employed in producing commodities for his own use. In either case, the additional produce obtained from the machine would have been an additional fund for the maintenance, of labour; and wages must, according to our elementary proposition, have risen.

We have thought it necessary to state this possible evil as a part of the theory of machinery, but we are far from attaching any practical importance to it. We do not believe that there exists upon record a single instance in which the whole annual produce has been diminished by the use of *inanimate* machinery. Partly in consequence of the expense of constructing the greater part of machinery being defrayed out of profits or rent, and partly in consequence of the great proportion which the productive powers of machinery bear to the expense of its construction, its use is uniformly accompanied by an enormous *increase* of production. The annual consumption of cotton wool in this Country, before the introduction of the spinning-jenny, did not exceed twelve hundred thousand pounds; it now amounts to two hundred and forty millions. The number of copies of books extant at any one period before the invention of the printing-press was probably smaller than that which is now produced in a single day. Mr. Ricardo's proposition, therefore, (*Princ.* 474.) that the use of machinery *frequently* diminishes the quantity of the gross produce of a Country, is erroneous, so far as it depends on the case which he has supposed, and of which we have stated the substance.

The other exception, that where the machine itself consumes commodities which would otherwise have been consumed by labourers, and that to a greater extent than it produces them, applies only to the case of horses and working-cattle, which may be termed animated machines. We will suppose a farmer to employ on his farm twenty men, who produce annually their own subsistence, and that of six other men producing commodities for the use of their master. If five horses, consuming, we will say, as much as eight men, could do the work of ten men, it would be worth the farmer's while to substitute them for eight of his men, as he would be able to increase the number of persons who work for his own benefit from six to eight. But after deducting the subsistence of the horses, the fund for the maintenance of labourers would be reduced from wages for twenty-six men to wages for eighteen. We cannot refuse to admit that such cases may exist, or to deplore the misery that must accompany them. They are, in fact, now occurring in Ireland, and are occasioning much of the distress of that Country. They seem, indeed, to be the natural accompaniments of a certain period in the progress of national improvement. In the early stages of society, the rank and even the safety of the landed proprietor is principally determined by the number of his dependents. The best mode of increasing that number is to allow the land, which he does not occupy as his own demesne, to be subdivided into small tenements, each cultivated by one family, and just sufficient for their support. Such tenants can of course pay little rent, but they are enabled by their abundant leisure, and forced by their absolute dependence, to swell the retinue, and aid the political influence, of their landlord in peace, and to follow his banner in public and private war. Cameron of Lochiel, whose rental did not exceed £500 a year, carried with him into the Rebellion of 1745 eight hundred men raised from his own tenantry. But in the progress of civilization, as wealth becomes the principal means of distinction and influence, landowners prefer rent to dependents. To obtain rent, that process of cultivation must be employed which will give, not absolutely the greatest amount of produce, but the greatest after deducting the expenses. For this purpose a tract of five hundred acres, from which fifty families produced their own subsistence, and produced scarcely any thing more, may be converted into one farm, and with the labour of ten families, and as many horses, may produce the subsistence of only thirty families. Fortunately, however, the period at which these alterations take place is generally one of great social improvement; so that, after a short interval, the increased diligence and skill with which labour is applied occasion an increase of the produce, after deducting the new

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expenditure. The fund for the maintenance of labourers now becomes increased from two different sources—partly from the increased efficiency of human labour when aided by that of horses and cattle, and partly from the results of a part of the human labour set free by the substitution of brutes. The ultimate consequences of such a change are always beneficial; the change itself must, in general, be accompanied by distress.

But with the exception of these two cases, one of which produces only temporary effects, and the other, though apparently possible, seems never actually to occur, it appears clear that the use of machinery must either raise the general rate of wages, or leave it unaltered.

When machinery is applied to the production of commodities which are *not* intended, directly or indirectly, for the use of labourers, it occasions no alteration in the general rate of wages; we say the *general* rate of wages, because it may diminish the rate of wages in some employments,—a diminution always compensated by a corresponding increase in some others. A small screw was shown to us at Birmingham which, in the manufacture of corkscrews, performed the work of fifty-nine men; with its assistance one man could cut a spiral groove in as many corkscrew shanks as sixty men could have cut in the same time with the tools previously in use. As the use of corkscrews is limited, it is not probable that the demand for them has sufficiently increased to enable the whole number of labourers previously employed in their manufacture to remain so employed after such an increase in their productive power. Some of the corkscrew-makers, therefore, must have been thrown out of work, and the rate of wages in that trade probably fell. But as the whole fund for the maintenance of labourers, and the whole number of labourers to be maintained, remained unaltered, that fall must have been balanced by a rise somewhere else—a rise which we may trace to its proximate cause, by recollecting that the fall in the price of corkscrews must have left every purchaser of a corkscrew a fund for the purchase of labour, rather larger than he would have possessed if he had paid the former price.

If, however, machinery be applied to the production of any commodity used by the labouring population, the general rate of wages will *rise*. That it cannot fall is clear, on the grounds which we have just stated. If the improvement be great, and the commodity not subject to a corresponding increase of demand, some of the labourers formerly employed in its production will be thrown out of employment, and wages, in that trade, will fall—a fall which, as the whole fund for the maintenance of labour is not diminished, must be met by a corresponding rise in some other trade. But the fund *will be increased* by the additional quantity produced of the commodity to which the improvement has been applied: estimated in that commodity, therefore, the general rate of wages, or, in other words, the quantity of commodities obtained by the labouring population, will be increased by the introduction of machinery; estimated in all others, it will be stationary.

The example taken from the manufacture of corkscrews is as unfavourable to the effects of machinery as can be proposed; for the use of the commodity is supposed to be unable to keep up with the increased power of production, and the whole number of labourers employed on it is, consequently, diminished. This, however, is a very rare occurrence. The usual effect of an increase in the facility of producing a commodity is so to increase its consumption as to occasion the employment of more, not less, labour than before.

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We have already called the reader's attention to the effects of machinery in the manufacture of cotton and in printing. Each of these trades probably employs ten times as many labourers as it would have employed if spinning-jennies and types had not been invented. Under such circumstances, (and they are the usual ones,) the benefits of machinery are not alloyed by even partial inconvenience.

Those who are little affected by inferences from general propositions may be influenced by a witness who states the results of his own observations. We will support our argument, therefore, by the following extract from Mr. Cowell's valuable preface to the tables of wages constructed by him in the performance of his duties as a Commissioner on the Factory Inquiry:—

"As long as the cotton-working continues to extend, the apprehensions entertained by the operatives of a fall in wages, either for adults or children, consequent upon improvements in machinery, are groundless. Their assertion is, (and it was repeated to me innumerable times,) that they have to turn out more work now for less wages than formerly. The *Manchester and Salford Advertiser*, which is the journal of the operatives, scarcely publishes a number which does not ring the changes on this assertion; and in that for the 11th of January, 1834, it asserts, 'that a spinner now turns out double the work for a tenth less wages than in 1804.'

"The matter stands thus: in 1804 a spinner was paid 8*s.* 6*d.* for every pound of yarn of the fineness of two hundred hanks to the pound, spinning on a mule of the average productive power of that time. What that productive power was I do not know. But in 1829 he was paid at the rate of 4*s.* 1*d.* for spinning the same quality on a mule of the productive power of three hundred and twelve; in 1831, and at present, at the rate of 2*s.* 5*d*, and 2*s.* 8½*d.* for spinning the same quality on a mule of the productive power of six hundred and forty-eight. These quotations are from the Manchester prices.

"Thus, in 1829, the spinner turned off three hundred and twelve pounds of yarn in the same time that he now takes to turn off six hundred and forty-eight. He was paid at the rate of 4*s.* 1*d.* per pound in 1829, he is now paid at the rate of 2*s.* 5*d.* But three hundred and twelve pounds at 4*s.* 1*d.* amount to one thousand two hundred and seventy-four shillings, and six hundred and forty-eight pounds at 2*s.* 5*d.* to one thousand five hundred and sixty-six shillings. He receives, therefore, two hundred and ninety-two shillings more than he did in 1829 for equal times of work. It is perfectly true that he does 'more work for less wages than in 1829;' but this is nothing to the purpose, when the proposition to be proved is, that 'wages are lower than formerly.' I mean to say, that a spinner earns a shilling, or a pound, or a hundred pounds, in less time at present than he would have consumed in earning a shilling, or a pound, or a hundred pounds, ten years ago, and with the same or less labour; that this enhancement of his earnings has been owing to improvements in machinery; that the progress of improvements will progressively advance his earnings still higher, and at the same time enable a greater number of individuals to profit by the enhanced rate than actually profits by the actual rate; (provided that nothing occurs to prevent the cotton business from developing itself for the next thirty years as it has done for

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the last;) and that any improvement in the machinery in any one of the numerous departments of cotton-working will operate to enhance the rate of wages in all other branches, (as well as in that department in which it takes place,) by increasing the actual previous demand for labour in those other branches. I assert that every improvement of cotton machinery, in any department of cotton-working, has hitherto had the effect of enabling 'an operative' (speaking in general of every one, in every department whatever) to earn a greater net amount of money, in any given time, than he would have done if the improvements had never taken place.

"The misconceptions as to the real effect of machinery on the wages of labour which the operatives entertain are the causes of turn-outs and strikes; they produce rankling discontent towards their masters, and I regret that I have not had the opportunity of giving them a fuller exposure.

"I certainly consider it of great consequence that the operatives themselves should be satisfied that improvements in machinery tend to raise the amount of money that they gain individually and generally, for the same number of hours' work. Those who dispute the fact must, I think, admit that I have established it in the cases which I have selected, as far as *spinners* are concerned; and as they must likewise admit that the improvement specified creates a fresh and additional demand for young hands, they must also admit that the wages of young hands are augmented in consequence. They must equally admit, that as the price of the article will be lowered in the market from the effects of the improvement, more of it will be consumed; and hence that, in all the correlate processes connected with spinning of cotton, more hands will be required, and consequently that wages throughout the whole range of cotton-working will be better than they were before. If these considerations should induce operatives to hesitate before they combine and turn out against new machinery, before they again cabal for shortening the hours of work, in order to counteract the (fancied) injurious effect upon wages of improvements in machinery, and should lead them to neglect the advice of those who urge them 'to strike for eight hours' work and twelve hours' earnings,' (and this is the advice they have lately received,) my purpose will be answered.

"The generality of the operatives in cotton-working are well meaning, respectable, shrewd, and sensible; and I believe that if the real effect of machinery in augmenting the actual rate of their earnings, and in enabling a greater number of persons to benefit by the augmented rate, could be fairly set before them and rendered familiar to their minds, it would have a most beneficial effect upon their actions as members of society." *Factory Inquiry Commission*, 2d Report. D. i. 119. n. m.

Population.

Fifthly. Closely connected with this mistake, and occasioned by the same habit of attending only to what is temporary and partial, and neglecting what is permanent and general; of dwelling on the evil that is concentrated, and being insensible to the benefit that is diffused, is the common error of supposing *that the general rate of wages can be reduced by the importation of foreign commodities*. In fact, the opening of a new market is precisely analogous to the introduction of a new machine, except that it is a machine which it costs nothing to construct or to keep up. If the foreign commodity be not consumed by the labouring population, its introduction leaves the general rate of wages unaffected; if it be used by them, their wages are raised as estimated in that commodity. If the laws which favour the wines of the Cape to the exclusion of those of France were repealed, more labourers would be employed in producing commodities for the French market, and fewer for that of the Cape. Wages might temporarily fall in the one trade, and rise in the other. The clear benefit would be derived by the drinkers of wine, who, at the same expense, would obtain more or better wine. So if what are called the protecting duties on French silks were removed, fewer labourers would be employed in the direct production of silk, and more in its indirect production, by the production of the cottons or hardware with which it would be purchased. The wearers of silk would be the only class ultimately benefited; and as the labouring population neither wear silk nor drink wine, the general rate of wages would, in both cases, remain unaltered. But if the laws which prohibit our obtaining on the most advantageous terms sugar and corn were altered, that portion of the fund for the maintenance of labour, which consists of corn and sugar, would be increased. And the general rate of wages, as estimated in two of the most important articles of food, would be raised.

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Employment.

Sixthly. The views which we have been endeavouring to explain are inconsistent with the common opinion, *that the unproductive consumption of landlords and capitalists is beneficial to the labouring classes, because it furnishes them with employment.* "Tillage," says Paley, (and this is another form of the same fallacy,) "is preferable to pasturage, not only because the provision which it yields goes much further in the sustentation of life, but because it affords *employment* to a more numerous peasantry." The production of more subsistence is certainly an advantage, but what is the advantage of its requiring more labour? If this be an advantage the fertility of land is an evil. If the thing required be *employment*, we should abandon ploughs and even spades. To scratch up a rood with the fingers would give more employment than to dig an acre. Those who maintain that unproductive consumption does good by affording employment, must forget that it is not employment, but food, clothing, shelter, and fuel, in short, the materials of subsistence and comfort, that the labouring classes require. The word "employment" is merely a concise form of designating toil, trouble, exposure, and fatigue. It is indeed sometimes elliptically used as implying the subsistence which is purchased by enduring it. A poor man complains that he wants *work*. He might work to his heart's content, and with no man's leave, if he chose to carry stones from the bottom to the top of a hill. But what he wants is work as a means of obtaining payment. He would be happy to get the payment without the work. Toil, exposure, and fatigue, *per se*, are evils, and the less of them that is required for obtaining a given amount of subsistence and comfort, or, in other words, the greater the facility of obtaining that given amount, the better, *cæteris paribus*, will be the condition of the labouring classes; indeed, of all classes in the community. What occasions the prosperity of a colony? Not the dearness of subsistence, but its cheapness; not the difficulty of obtaining food, clothing, shelter, and fuel, but the facility. Now how can unproductive consumption increase this facility? How can the fund from which all are to be maintained be augmented by the destruction of a portion of it? If the higher orders were to return to the customs of a century ago, and cover their coats with gold

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lace, they might enjoy their own finery; but how would that benefit their inferiors? The theory which we are considering replies that they would be benefited by being *employed* in making the lace. It is true that a coat, instead of costing £5, would cost £55. But what becomes *now* of the extra £50? for it cannot be said that, because it is not spent on a laced coat, it does not exist. If a landlord with £10,000 a year spends it unproductively, he pays it away to those who furnish the embellishments of his house and grounds, and supply his stable, his equipage, and his clothes. Suppose him now to abandon all unproductive expenditure, to confine himself to bare necessaries, and to earn them by his own labour, the first consequence would be, that those among whom he previously spent his £10,000 a year would lose him as an employer; and beyond this the theory in question sees nothing. But what would he do with the £10,000 which he would still annually receive? No one supposes that he would lock it up in a box, or bury it in his garden. Whether productively or unproductively, it still must be spent. If spent by himself, as by the supposition it would be spent productively, it must increase, and every year still further increase, the whole fund applicable to the use of the rest of the community. If not spent by himself, it must be lent, as is done by a miser of the present day, to some other person, and by that person it must be spent productively or unproductively. He might, perhaps, buy with it property in the English funds; but what becomes of it in the hands of the person who sells to him that funded property? He might buy with it French rentes; but in what form would the price of those rentes go to Paris?—In the form, as we have seen, of manufactured commodities. *Quâcunque viâ datâ*, every man must spend his income; and the less he spends on himself, the more remains for the rest of the world.

The seventh and last theory inconsistent with our own views, to which we shall call the reader's attention, is that proposed by Mr. Ricardo in the following passage:—

Preference of services to commodities.

"The labouring class have no small interest in the manner in which the net income of the Country is expended, although it should, in all cases, be expended for the gratification and enjoyment of those who are fairly entitled to it.

"If a landlord, or a capitalist, expends his revenue in the manner of an ancient Baron, in the support of a great number of retainers or menial servants, he will give employment to much more labour than if he expended it on fine clothes or costly furniture.

"In both cases the net revenue would be the same, and so would be the gross revenue, but the former would be realized in different commodities. If my revenue were £10,000, the same quantity nearly of productive labour would be employed, whether I realized it in fine clothes and costly furniture, &c. &c., or in a quantity of food and clothing of the same value If, however, I realized my revenue in the first set of commodities, no more labour would be *consequently* employed: I should enjoy my furniture and my clothes, and there would be an end of them; but if I realized my revenue in food and clothing, and my desire was to employ menial servants, all those whom I could so employ with my revenue of £10,000, or with the food and clothing which it would purchase, would be to be added to the former demand for labourers, and this addition would take place only because I chose this mode of expending my revenue. As the labourers, then, are interested in the demand for labour, they must naturally desire that as much as possible should be diverted from expenditure on luxuries, to be expended in the support of menial servants.

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"In the same manner a Country engaged in war, and which is under the necessity of maintaining large fleets and armies, employs a great many more men than will be employed when the war terminates, and the annual expenses which it brings with it cease.

"If I were not called upon for a tax of £500 during the war, which is expended on men in the situations of soldiers and sailors, I might probably spend that portion of my income on furniture, clothes, books, &c. &c., and whether it was expended in the one way or the other, there would be the same quantity of labour employed in production; for the food and clothing of the soldier and sailor would require the same amount of industry to produce them as the more luxurious commodities: but, in the case of war, there would be the additional demand for men as soldiers and sailors; and, consequently, a war which is supported out of the revenue, and not from the capital of a Country, is favourable to an increase of population.

"At the termination of the war, when part of my revenue reverts to me, and is employed as before in the purchase of wine, furniture, or other luxuries, the population which it before supported, and which the war called into existence, will become redundant, and by its effect on the rest of the population, and its competition with it for employment, will sink the value of wages, and very materially deteriorate the condition of the labouring classes." *

Mr. Ricardo's theory is, that it is more beneficial to the labouring classes to be employed in the production of services than in the production of commodities; that it is better for them to be employed in standing behind chairs than in making chairs; as soldiers or sailors than as manufacturers. Now, as it is clear that the whole quantity of commodities provided for the use of labourers is not increased by the conversion of an artisan into a footman or a soldier, either Mr. Ricardo must be wrong, or our elementary proposition is false.

Mr. Ricardo seems to have been led to his conclusions by observing that the wages of servants, sailors, and soldiers are principally paid in kind—those of artisans in money. He correctly states, that if a man with £10,000 a year spends his income in the purchase of commodities for his own use, he retains, after having made those purchases, no further fund for the maintenance of labour; but that if he spends it in the purchase of commodities to be employed in maintaining menial servants, he has, in those purchased commodities, a new fund with which he can maintain a certain number of menial servants. It appeared to him, therefore, that the landlord would, in the latter case, be able to spend his income twice over; to subsist twice as many persons as before. It did not occur to him that the landlord, by purchasing himself the subsistence of his servants, merely does for them what they would be able to do better for themselves; that, instead of spending his own income twice over, he merely takes on himself the business of spending theirs for them. He did not perceive that all that the landlord spends in purchasing the subsistence and clothing of his servants, is so much deducted from what he would otherwise have to pay to

* *Principles, &c.* p. 475.

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them in money, to be by them employed in the purchase of subsistence and clothing; and that if he were to give to his servants the value of their whole subsistence in money, the whole body of labourers would be just as well maintained as in the supposed case of his purchasing their subsistence, and then giving it to them in exchange for their services. No one would maintain that, if it were the general practice, in this Country, as it is in India, to give to servants board wages, the demand for labour would be lessened; or that if it were the practice, as it is in semi-barbarous Countries, to maintain servants to produce within their masters' walls the commodities which we are accustomed to purchase from shops, such as the fine clothes and furniture to which Mr. Ricardo alludes, the demand for labour would be increased. Still less could it be maintained, that if those servants, instead of producing commodities, were employed in following their master's person, or mounting guard before his door, such a change would create an additional demand for men, and be favourable to an increase of population.

So far are we from concurring in Mr. Ricardo's opinion, that it is the interest of the labourers that revenue should be spent rather on services than on commodities, that we believe their interest to be precisely opposite. In the first place, the labourer can generally manage better his own income than it can be managed for him by his master. If a domestic servant could earn as wages the whole sum which he costs his master, even if he were to spend it as he received it, he would probably spend it with more enjoyment. Secondly, the income spent on services is generally spent in the purchase of what perishes at the instant of its creation; that spent on commodities often leaves results which, when their first purchaser has done with them, are serviceable to others. In this Country the poor are, to a great extent, clothed with garments originally provided for their superiors. In all the better class of cottages may be found articles of furniture which never could have been made for their present possessors. A large portion of the commodities which now contribute to the comfort of the labouring classes would never have existed if it had been the fashion in this Country, during the last fifty years, to prefer retinue and attendance to durable commodities. And, thirdly, the income employed on commodities is favourable to the creation of both material and immaterial capital; that employed on services is not. The duties of a servant are so easily learned, that he can scarcely be termed a skilled labourer; his accumulations are small in amount, and seldom turned to much advantage. The artisan learns a trade, in which every year adds to his skill, and is taught mechanical and chemical processes, often susceptible of indefinite improvement, and in which a single invention may raise the author to wealth, and diffuse prosperity over a whole district, or even a whole nation. An industrious artisan can often save a large portion of his income, and invest it with great and immediate profit. He purchases with his savings a small stock of tools and materials, and, by the vigilance and activity which can be applied only to a small capital, renders every portion of it efficient. The ancestors, and not the remote ancestors, of some of our richest and our proudest families, the authors of some of our most valuable discoveries, were common mechanics. What menial servant has in this Country, and in modern times, been a public benefactor, or even raised himself to affluence? Both history and observation show that those Countries in which expenditure is chiefly employed in the purchase of services are poor, and those in which it is chiefly employed on commodities are rich.

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Mr. Ricardo's theory as to the effects of war is still more strikingly erroneous. It is, in the first place, open to all the objections which we have already opposed to his views respecting menial servants. The revenue which is employed in maintaining soldiers and sailors would, even if unproductively consumed, maintain at least an equal number of servants and artisans; and that portion of it which would have been employed in the maintenance of artisans would (as we have seen) have been far more beneficially employed. The demand for soldiers and sailors is not, as he terms it, an additional, it is merely a substituted, demand. But a great part of that revenue would have been productively consumed. Instead of employing some labourers in converting suburbs into fortifications, and forests into navies, to perish by dry rot in harbour, or by exposure at sea, and others in walking the deck and parading on the rampart, it would have employed them in adding more and more every year to the fund from which their subsistence is derived. War is mischievous to every class in the community; but to none is it such a curse as to the labourers.

We have now explained the principal errors which are inconsistent with our elementary proposition, namely, that *the quantity and quality of the commodities obtained by each labouring family during the year must depend on the quantity and quality of the commodities directly or indirectly appropriated during the year to the use of the labouring population, compared with the number of labouring families, or, to speak more concisely, on the extent of the fund for the maintenance of labourers, compared with the number of labourers to be maintained.*

On what, then, does the extent of that fund depend? In the first place, on the productiveness of labour in the direct or indirect production of the commodities used by the labourer; and, in the second place, on the number of persons directly or indirectly employed in the production of things for the use of labourers, compared with the whole number of labouring families. If we wished to ascertain the comparative wages of the labouring population in two parishes, containing each, we will say, twenty-four labouring families, these are the only two points to which we need direct our inquiries. If we found that in the one parish eighteen families, and in the other only twelve, were employed in producing commodities for the whole twenty-four, we should infer that, supposing the labour of each to be equally productive, wages must be higher by one-fourth in the first than in the second. But if we found that in the second parish labour was more productive by one-half than in the first, we should infer an equality of wages in the two.

Productiveness of labour.

We will begin by considering the causes which affect the productiveness of labour in the direct or indirect production of the commodities, used by the labourer. We add the word *indirect*, not with reference to the whole fund which supplies the maintenance of all the labourers throughout the world, but with reference to the fund which supplies the wants of the labourers in a particular Country. If we consider the whole world as forming one community, it is obvious that the fund for the subsistence of the labouring por-

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tion of that community cannot be increased by the increased production of those commodities which they do not use; by the increased production, for instance, of lace or statues.

But the fund for the maintenance of the labourers in any given Country may be, and often is, materially dependent on the facility with which they can produce commodities useless to themselves except as the instruments of exchange. The tea, the tobacco, and the sugar used by our labouring population are principally obtained in return for exported commodities unfitted for our climate and our habits. But the superior facility with which we produce those exported commodities enables, or, if legislative interference did not prevent it, would enable, our labouring population to obtain tea, sugar, and tobacco with less labour than they cost in the Countries of which they are the natural growth. It is unimportant to the labourer whether his corn is the produce of the soil of England or of Poland; whether it is obtained directly by means of the plough, or indirectly by means of the loom.

On what then does the first of these two causes, namely, the productiveness of labour, depend?

First. It depends partly on the corporeal, intellectual, and moral qualities of the labourer; on his diligence, his skill, and his strength of body and mind. And these depend on causes, many of which are imperfectly understood, and others are too complicated to admit of concise explanation, or to be fully considered without entering into investigations connected indeed with Political Economy, but not within its peculiar province. Much may depend on race and on climate; much more depends on religion, education, and government. One cause only we shall slightly dwell on, because it is simple, and has not been sufficiently considered by any writers except M. Quetelet,* and Sir F. D'Ivernois,† and that is, the mean age of the labouring population. This depends partly on the average duration of life in a Country, and partly on the rate at which its population is increasing. In England, the average duration of life is supposed to amount to about forty-four years. In many Countries it does not reach thirty-five; in some it does not attain twenty-five. Again, in some Countries the population doubles every twenty-five years. At the present rate of increase in England it would double in about fifty. The average period of its doubling throughout Europe is supposed to be about a century.

Now it is obvious that, the number of persons and the rate of increase in any two Countries being given, that Country would have the greater number of adults in which the average duration of life was the longer; and, the longevity being given, that Country would have the greater proportion of adults in which the rate of increase was the slower. Longevity, and a population stationary or slowly increasing, are therefore favourable to the productiveness of labour.

Secondly. The corporeal, intellectual, and moral qualities of the labourer being given, the productiveness of labour in any Country will partly depend on the natural agents by which it is assisted, or, in other words, on the climate, soil, situation, and extent in proportion to its population, of that Country.

To some Countries nature has refused the means of supporting human life; to others she has refused the means of wealth. No exertions would enable a community to exist long on Melville Island, or in the Deserts of Africa, or to exist comfortably in Greenland or Nova Zembla. But, though she can deny riches, she cannot give them. The finest districts in the world are among the poorest. With all the brute and inanimate sources of affluence profusely scattered before them, the inhabitants of the greater part of Africa, America, and Asia want the moral and intellectual qualities by which the raw materials of wealth are to be worked up. Even the Icelanders seem to be richer than the Guachos. But, although local advantages are far from being the most efficient causes of the productiveness of labour, their influence must not be disregarded. They have enabled the colonies of highly civilized nations to advance to opulence with a rapidity of which we have no other example.

Thirdly. The productiveness of labour partly depends on the degree in which it is assisted by abstinence, or, to use a more familiar expression, by the use of capital.

We have already explained the advantages afforded by capital, and traced them to the use of implements and the division of labour, and need only remind our readers that, of all means by which labour can be rendered productive, the use of capital is far the most efficient. Without tools, and without the division of employments, man would be an animal less capable of obtaining enjoyment, or even subsistence, than the brutes of the field.

Fourthly. The last of the causes which influence the productiveness of labour is the existence or the absence of government interference.

The essential business of government is to afford defence; to protect the community against foreign and domestic violence and fraud. Unfortunately, however, governments have generally supposed it to be their duty, not merely to give *security* but *wealth*; not merely to enable their subjects to produce and enjoy in safety, but to teach them *what* to produce and *how* to enjoy; to give them instruction how to manage their own concerns, and to force them to obey that instruction.

Unfortunately, too, the ignorance and folly with which they have attempted to execute this office have been equal to the ignorance and folly which led them to undertake it. Partly under the influence of what has been called the mercantile theory, the theory which teaches that wealth consists of gold and silver, and may be indefinitely increased by exporting commodities, and receiving only money in return; and partly misled by the circumstance, that when an individual, or a class, obtains a monopoly against the public, the loss, however great, becomes imperceptible from its diffusion, and the gain, however trifling, is obvious, because it is concentrated, it has long been the ruling principle of commercial statesmen to favour direct at the expense of indirect production; to refuse participation in the benefits bestowed by nature on foreign Countries, though at the expense of surrendering a portion of what she has conferred on their own; and to force the industry of their subjects from those channels in which they have peculiar advantages, into those for which their climate, their habits, and their soil are inappropriate.

It is under the influence of these causes that the civilized world has lately exhibited the strange spectacle of general peace accompanied by general distress. During the War, the greater part of Southern Europe had coalesced into one vast Empire; a single Sovereign

* *Sur l'Homme,* tome i. p. 324.

† *Sur la Mortalité Proportionelle, &c.*

ruled from Hamburgh to Rome; and hundreds of lines of custom-houses and revenue-officers, that had previously interposed against commerce barriers more impassable than seas or mountains, were swept away. Napoleon was deeply steeped in the mercantile theory, and his conduct shows how completely his views were founded on unreflecting prejudice. In obedience to that theory, he believed free trade between independent States to be like gambling between individuals, and therefore mischievous to the one or to the other: mischievous in fact to the one which, in the ultimate settling of accounts, had to pay a balance in money. While France and Italy were under different rulers, he therefore must have believed that the inhabitants of one of the two Countries would be injured by being allowed to purchase the commodities of the other. But the framers of the mercantile theory, blind as they were, had never ventured to object to the freest intercourse between the inhabitants of contiguous districts in the same Empire. When he had forced under his yoke Belgium and France, he allowed them therefore a freedom of intercourse which he still prohibited between France and Austria; totally forgetting that the benefit of an exchange does not depend on the accident, whether the parties to it are, or are not, fellow-subjects. His theories were servile copies of errors unhappily too prevalent, and faded away before his strong common sense on the slightest variation of appearances, though the facts on which the question turns were unaltered.

On the termination of the War, Napoleon's Empire was broken up into independent Kingdoms, and each State set to work to reimpose on itself the fetters which his powerful hand had broken. Douaniers and preventive-service men were found instruments as efficient in wasting the resources of their own Country, and in arresting the improvement of their neighbours, as armies and fleets. The produce of France became contraband in Belgium and Italy, and the produce of Belgium and Italy in France. America solemnized the Peace by a tariff, and England by a corn law. To prohibit whatever is wanted became again the rule in commercial policy. Russia is an agricultural Country; she therefore forbad the import of foreign manufactures. England is abundantly supplied with manufactures, she therefore prohibited corn.

We are inclined to think that the conduct of Russia was practically more mischievous than that of England. She has adhered to the anti-commercial system with far more pertinacity than we have; indeed, every change which she has made, has been to add to duties, and to extend prohibitions. But the objections in principle against the exclusion of raw produce seem to us still more forcible than those against the exclusion of manufactures. In the first place, the consumption of the labourer consists principally of raw produce, or slightly worked commodities. No restrictions on the importation of the finer manufactures can affect him. But laws against the importation of raw produce are specifically directed against the labouring population. Their professed object is to diminish, in fact, the principal fund for the maintenance of labour. And, secondly, when an agricultural Country prohibits foreign manufactures, the labourer is, to a certain extent, indemnified by a consequent fall in the price of raw produce. On the other hand, when a manufacturing Country prohibits the importation of raw produce, the price of all commodities, excepting labour, has a tendency to increase, and the labourer finds it more difficult to obtain *every* article of his consumption.

This may require some explanation. We have already shown, that every additional quantity of raw produce is, generally speaking, obtained at a greater proportional expense. To prohibit the importation of manufactures is, of course, to prohibit the exportation of the raw produce, which otherwise would have been employed in purchasing them. As a smaller quantity of raw produce is wanted, a smaller quantity is produced, and that quantity is produced at a less proportionate expense; labour, though less productive in clothes and furniture, becomes more productive in raw produce; the price of raw produce, therefore, falls, and the labourer, in having less to pay for food, obtains some compensation for having more to pay for other commodities. The greater part of the evil falls on the proprietors of the land. On the contrary, every additional quantity of manufactured produce is obtained, so far as the manufacturing of it is concerned, at a less proportionate expense. Every increase of the supply is accompanied by the introduction of more and better machinery, and by a further division of labour. As in the former case, restrictions on the importation of raw produce are, in fact, restrictions on the exportation of manufactures. Fewer manufactured commodities being wanted, and consequently fewer produced, what are produced are produced at the expense of proportionately more labour than would otherwise be necessary. More raw produce must be raised at home, and that also must be raised at a greater proportionate expense of labour. The price of the one kind of commodities rises, because it has become necessary to produce more, and that of the other, because it has become necessary to produce less. The productiveness of labour is diminished each way, and the only person uninjured is the landlord.

To a certain extent, however, the misdirection of industry by government interference is a necessary evil. The duties of government cannot be performed without a public revenue; nor can a considerable public revenue be raised without taxation; and the struggle to escape taxation always tends to divert industry from its natural channels. The tax which is least open to this objection, a tax on rent, must tend to prevent the application of capital to land; a tax on profits to occasion the exportation of capital; a tax on income derived from property to prevent accumulation; a tax on wages to occasion their payment rather in kind than in money, and to prevent the labourer from acquiring durable and visible property in the hope of pleading his poverty as an excuse. Taxes on specific articles are evaded by the substitution of some less burdened or cheaper commodity. The beer and malt duties are avoided by the substitution of spirits. The duties on tea and coffee by the use of roasted corn. Now, every tax, so far as it is evaded, is simply mischievous. A window blocked up to avoid window tax may diminish the light and air enjoyed by a whole family, but adds nothing to the public revenue. A distinct and a still greater injury arises from taxation imposed on the instruments and processes of industry. The salt tax, while it existed, prevented in a great measure the use of salt in agriculture. The duty on advertisements prevents vendors and purchasers from knowing each other's wants and supplies. The duties on leather, on spirits, and on glass, have not only prevented England from attaining, in the manufacture of those commodities, her usual superiority, but have kept her positively behind the improved part of Europe. To

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prevent fraud on the Excise, the manufacturer is subject to innumerable regulations and prohibitions incompatible with a proper economy of materials and division of labour, and which bend very reluctantly to improvements. To improve is necessarily to alter, and any alteration in the process prescribed by law may entangle the manufacturer within the meshes of a regulating Act of Parliament.

It is commonly supposed that men are sufficiently ready to grumble at taxation; but the fact that they are very imperfectly aware of the degree and kind of evil indirectly inflicted might be proved from many instances. To select only one. Most persons are aware of the far higher price borne by good malting barley above the ordinary barley used only for feeding stock; nor can any one doubt that the price of beer is materially enhanced by this circumstance. But, probably, not one consumer in ten thousand has any idea that this is connected with taxation. Yet, in fact, a large proportion of the barley set aside as unfit for malting would make, as far as nature is concerned, very good malt, but requires a process somewhat different from that which the Excise regulations prescribe, and is consequently rendered by law useless for that purpose. It may easily be conceived that, if the times and mode of ploughing, harrowing, and sowing were prescribed by law, a large portion of land now productive would lie waste.

A Country which has been forced by the folly or the rapacity of its own government, or by the folly or rapacity of other States, to raise a large public revenue, suffers in general far more from the indirect than from the direct effects of taxation; suffers more by being prevented from producing, than by being obliged to pay.

The causes which determine the productiveness of labour in the direct or indirect production of the commodities used by the labourer appear, therefore, to be four. First, the personal character of the labourer, his corporeal, intellectual, and moral qualities; secondly, the degree in which he is assisted by natural agents; thirdly, the degree in which he is assisted by capital; fourthly, the degree of freedom with which he is allowed to direct his industry.

Proportion of Persons employed in the Production of Commodities for the Use of Labourers to the whole Number of Labouring Families.

If all labourers were employed in the production, direct or indirect, of commodities for their own use, the rate of wages would depend solely on the productiveness of labour. But it is obvious that this could never be the case, unless the labourers themselves were the owners of all the capital and all the natural agents of the country; a state of existence so utterly barbarous as to be without distinction of ranks or division of labour; a state in which a few scattered savage families have sometimes been found, but which exhibits none of the phenomena which it is the business of Political Economy to trace to their causes. A great portion of the labour employed in a civilized community is employed in the production of things in the use of which the labourer is not to participate. In a civilized community, therefore, the extent of the fund for the maintenance of labour depends not only on the productiveness of labour, but also on the number of persons employed in the production of things for the use of labourers, compared with the whole number of labouring families.

Distribution. Wages. Direction of labour. Rent.

It appears to us that there are three purposes to which labour, which might otherwise be employed in supplying the fund for the use of labourers, may be diverted; namely, the production of things, first, to be used by the proprietors of natural agents; secondly, to be used by the government; and thirdly, to be used by capitalists; or, to speak more concisely, though less correctly, labour, instead of being employed in the production of wages, may be employed in the production of rent, taxation, or profit.

Direction of labour. 1. To rent.

First, with respect to rent.

We have already seen that rent depends in part on the productiveness of the natural agent for the assistance of which it is paid. Now any increase in the productive powers of that agent has a tendency to increase rent, and can have none to diminish wages.

The improvements in agricultural skill which have taken place during the last one hundred years have greatly increased the productiveness of the Lowlands of Scotland, and greatly increased the amount of rent; but that increase has been accompanied by an increase, though not in an equal ratio, of the amount of wages. Adam Smith states, that at the time when he wrote (the period of the American War) the usual price of common labour there was 8*d.* a day, or 4*s.* a week. It is now more than 8*s.* a week; a sum capable of purchasing one-third more of raw produce, and three or four times as much of manufactured produce, as the former wages. Though the rental of the Lowlands has more than tripled, though a much larger portion of what the labourer produces is produced for the benefit of the landlord, yet the positive increase of the whole produce more than compensates this apparent inconvenience. Instead of producing, we will say, twenty bushels, of which the landlord received ten, the capitalist two, and the labourer eight, he produces perhaps thirty-five, of which the landlord receives twenty, the capitalist three, and the labourer twelve.

It appears, therefore, that the whole fund for the maintenance of labour is not necessarily diminished in consequence of a considerable portion of the labourers in a Country being employed in producing commodities for the use of the proprietors of the natural agents in that Country. Such labourers may, in fact, be considered as existing only in consequence of the existence of natural agents of extraordinary productiveness. They draw their subsistence not from the common fund, such as it otherwise would be, but from the addition made to that fund by that extraordinary productiveness.

Of course, when we speak of the amount of rent as unimportant to the labourer, we must be understood to mean only that rent which arises from the peculiar or increased productiveness of the natural agent in question, not of that which arises merely from an increase of population. We have already stated that, in the absence of disturbing causes, subsistence may be expected to increase in a greater ratio than population. But, as we then remarked, it certainly is possible, and perhaps, under the influence of superstition and misgovernment, it is probable, that the number of inhabitants in a Country might increase without a commensurate increase of the means, direct or indirect, of obtaining raw produce. Under such circumstances, rents would rise, and labour, which, if the population had remained stationary, would have been employed in the production of commodities for the use of labourers, would now be employed in producing commodities for the use of landlords. A

Distribution. Wages. Direction of labour to supply consumption of government.

rise of rent so occasioned would of course be detrimental to the mass of the community. It must be recollected, also, that the government of every Country has in some measure the power of deciding in what proportions the different classes of its subjects shall contribute to the public burdens. Some governments have attempted to exempt, as far as they could, the labourers from these burdens, and to throw them as far as they could upon the landlords. Others again have charged, or have allowed individuals to charge, the revenue arising from land with an expenditure for purposes in which the landlords were not solely or principally interested; such as the establishment and maintenance of roads and bridges, the supply of religious, moral, and intellectual instruction, the affording gratuitous medical relief to the sick, and even support to the able-bodied poor or their families. Others, on the other hand, have endeavoured to favour the landlords by imposing public expenditure on the more defenceless portion of the community, the labourers; and many have adopted each of these different lines of conduct on different occasions, or with respect to different portions of their expenditure. The tendency of every such institution must be to augment or diminish the proportion of the labourers employed for the benefit of landlords, compared with that of those who are employed for the benefit of labourers.

Another cause disturbing these proportions is the attempt by a government to create rent, if it can be called rent, by forcibly limiting the bounty of nature. It is possible that, if we had continued to prohibit the corn of Ireland, the incomes of English landlords might have been increased. So, if no coal were allowed to be burned except the produce of a single colliery, the possessor of that colliery would enjoy a princely revenue. But the gain from such a monopoly is not strictly rent; it is oppression and robbery.

2. Direction of labour to supply the consumption of government.

The second purpose to which labour may be diverted from the supply of commodities for the use of labourers is the supply of the consumption of government. It is clear that all the labour that is employed in the support of *unnecessary* establishments, and all the surplus labour which is employed in supporting on an unnecessary scale of expense those establishments which are strictly wanted, is so much taken from the revenue of the whole people. Still more injurious is the employment of labour for the purposes not merely useless, but positively mischievous; in the support of pagodas or bonzes, to keep up or disseminate a demoralizing superstition; in the support of armies and navies to plunder the commerce and ravage the territories of States, which nature enabled to confer mutual benefits, but the folly or wickedness of their rulers force to inflict mutual evil; or in the support of barriers and blockades to maintain the commercial war in which nations are accustomed to spend the breathing time of actual hostility. Unnecessary taxation, even when innocently applied, is fraud or robbery. It is difficult to find a designation for that which is applied to ends still more mischievous than the means; for that which makes plunder and extortion the instruments of still further injury.

It appears at first sight that only this mischievous or useless expenditure ought to be considered as a deduction from wages, since the labour which is employed in effecting the legitimate purposes of government is as much employed for the benefit of the labouring classes as that which is employed in the direct production of commodities for their use. The great object of government is to afford security, and security is of all blessings the most important, and the one least capable of being obtained by uncombined exertions. Those writers who have maintained that whatever is raised by taxation is deducted from the revenue of the Country, seem to have been led to this conclusion, by observing that the object of government is to occasion not positive but negative effects, not to produce good, but to prevent evil. And they have thought it right to deduct what is so spent from the net revenue of the people. But it must be recollected that the mere prevention of evil is one of the principal objects even of individual expenditure. We do not build houses because it is pleasant to breathe the confined atmosphere of a room, but because roofs and walls are the only means by which the inclemency of the seasons can be avoided. We do not buy drugs for our pleasure, but to avert or remove disease. Yet no one ever thought what he spends on medicines and on house rent a deduction from his income. When the members of a Friendly Society raise among themselves a fund for their relief in sickness, they do not consider their contributions a deduction from their wages, but a mode of expenditure. And it may be asked, in what respect does each man's contribution towards the means by which the community is to be protected against internal and external violence and fraud differ from his contribution to a Friendly Society, excepting that those evils are more severe and more constantly imminent than sickness, and less capable of being warded off by individual efforts? It is true that, if the protection could be less expensively obtained, the fund for the maintenance of labour would be increased. But this is merely an exemplification of what we have already stated, that the extent of the fund for the maintenance of labour depends mainly on the productiveness of labour. If fewer fleets, and armies, and magistrates, could preserve the peace, that is, if labour were more productive in affording security, the labouring clases would, *cæteris paribus*, be better off, just as they would be better off if fewer husbandmen or artisans could produce, directly or indirectly, the same quantity of corn; that is, if labour were more productive in supplying food.

But admitting all this to be true, it is also true, as we have already remarked, that the labourer is interested not only in the amount and application of the public revenue, and in the degree in which its payment affects the productiveness of labour, but also in the manner in which the burthen of supplying it is distributed. If the duty on wine were abolished, and an equal revenue raised by substituting an additional duty on coarse tobacco, the labourers, who are the only consumers of coarse tobacco, would purchase, with the same proportion of their wages, less tobacco than before, and the landlords and capitalists, who are the only consumers of wine, would purchase, with the same proportions of their rents and profits, more wine. The productiveness of our labour and the export of our manufactures would be undiminished; even the nature of our exports need not be altered; the only change would be in the returns. More wine and less tobacco would be imported. More labourers, therefore, than before would be employed in obtaining wine for landlords and capitalists, and fewer in obtaining tobacco for labourers.

Nor must it be forgotten that a part of the taxes

Political Economy. Distribution. Wages and Profits.

received by the government of one Country is often paid by the inhabitants of another. We now purchase annually in China about thirty millions of pounds of tea, at about 1*s*. a pound. On the tea so purchased we impose in different ways taxes to the amount of about two hundred per cent. Were we to repeal that taxation, and the price in China were to remain unaltered, our consumption would probably quadruple; but it is highly improbable that we could purchase one hundred and twenty millions of pounds of tea at 1*s*. a pound. The price in China might possibly double; it probably would rise one-half. That rise would have a tendency to raise the rent of land and the wages of labour in the tea-growing districts of China. It must be admitted, therefore, that they are both kept down by the existence of the tax; and that a portion of our duty on tea is, in fact, paid by the inhabitants of the tea-growing districts of China. The same reasoning proves that a part of the English duty on claret is paid by France, and that a part of the duties imposed by foreign nations on some of the commodities which we export, is paid by England. As a portion of the taxes raised by every State is, in fact, paid by the inhabitants of those Countries with which it has commercial relations, and as war and misgovernment are the great causes of taxation, an additional proof is afforded of the degree in which each Country is interested in the freedom and tranquillity of its neighbours.

We have lastly to consider the influence of profits on wages; or, in other words, the extent to which wages may be affected by the employment of labour to produce, instead of wages, things for the use of capitalists. In civilized and well-governed communities, this is the principal purpose to which labour, that otherwise might be employed for the benefit of the labourers, is diverted. The labourers who are employed for the benefit of the owners of natural agents may, as we have seen, be in general considered as a separate class, not withdrawn from the general body, but added to it by the existence of those natural agents. Those who are necessarily employed in effecting the legitimate purposes of government are, in fact, employed for the benefit of the labouring population, and the taxation which supplies their maintenance is not necessarily a deduction from wages, but a mode of expenditure. That few governments have confined themselves to their legitimate office, or employed in effecting that office only the necessary amount of labour, is a melancholy truth; and it is true that the fund for the maintenance of labour may be, and in most Countries has been, and is, more diminished in its amount, and more retarded in its increase, by misgovernment than by all other causes put together. But both misgovernment and that interference of the ruling power between the different classes of its subjects which we have already described as affecting the proportions of rent, profit, and wages to one another, are rather disturbing causes than necessary elements in the calculations of Political Economy; and with these allusions to their influence we shall dismiss them.

Influence of profit on wages.

Rent then being considered as something extrinsic, and taxation a mode of expenditure, the only remaining deduction from wages is profit. And the productiveness of labour being given, the extent of the fund for the maintenance of labour will depend on the proportion which the number of labourers employed in producing things for the use of capitalists bears to that of those employed in producing things for the use of labourers; or, to use a more common expression, on the proportions in which the produce of labour is shared between the capitalist and the labourer.

In a previous portion of this Treatise we defined the word "abstinence" to mean the conduct of him who abstains from the unproductive consumption of any commodity, or who employs labour to produce distant results. In fact, the act of deferring enjoyment. And we explained that labour cannot be efficient unless assisted by, what is the result of abstinence, capital; nor abstinence in itself efficient unless assisted by labour; that each is disagreeable, and must therefore be called into exertion by the prospect of its specific remuneration; abstinence by the hope of profit, and labour by the hope of wages: and we stated, that although in fact the same individual often undergoes both abstinence and labour, yet that we thought it more convenient to consider the capitalist and the labourer as different persons. In the absence of rent, and of unnecessary or unequally distributed taxation, it is between these two classes that all that is produced is divided; and the question now to be considered is, what decides the proportion of the shares?

The facts which decide in what proportions the capitalist and labourer share the common fund appear to be two: first, the general rate of profit in the Country on the advance of capital for a given period; and, secondly, the period which in each particular case has elapsed between the advance of the capital and the receipt of the profit.

General rate of profit.

First, as to the general rate of profit. We have seen that profit is the remuneration of abstinence, and that abstinence is the deferring of enjoyment. The commodity which owes its existence or its preservation to abstinence is capital. Its owner is termed a capitalist, and he is said to *advance* the means by which it is created or preserved. These means are partly materials and implements, (including, under the last term, not merely the ordinary tools of manual labour, but machinery, ships, and even roads, wharfs, and canals,) and partly labour. The materials and implements are supplied by the capitalist directly, the labour is supplied by him indirectly, by advancing the wages of the labourers. The labourers, aided by their implements, convert the materials into a new and vendible commodity, which is termed the *return* of the capitalist. And the capitalist's profit depends on the difference between the value of the advance and the value of the return. In producing the return, the wages and materials are necessarily consumed; they are parted with by the capitalist, and therefore termed circulating capital. The implements are not necessarily consumed; so far as they are unconsumed they remain the property of the capitalist, and are therefore termed fixed capital. The value of that portion of them which remains unconsumed must be added to that of the other returns before the profit can be estimated. The capital of a builder is almost entirely circulating. It consists principally of the bricks, lime, timber, stone, and slate which are the materials with which the house is to be constructed, and of the money necessary to pay the wages of the workmen. His fixed capital (exclusively of his knowledge) consists merely of scaffolding and ladders. All these he advances, and the result, after a certain interval, is a house, together with the former ladders and scaffolding somewhat the worse for wear. The cotton-spinner's advances consist of raw cotton and wages, which are his circulating capital, and buildings and machinery, which are his fixed capital.

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His returns are a certain quantity of manufactured cotton, and the old buildings and machinery. So a ship-owner's advances consist of his ship, which is his fixed capital, and of its stores, and the wages of his sailors, which are his circulating capital; his returns are his freight, or, in other words, the hire which he receives for the use of his ship, the ship itself, such as it may be, after the voyage, and the stores, if any of them remain unconsumed. The profit in every case consists, as we have already stated, of the difference between the value of the advances and the value of the returns.

How to be estimated.

But in what is this value to be estimated? Of course in something as unsusceptible as possible of variations in its general value. If the value of the advances and returns of the capitalist were estimated in corn or in hops, an abundant season might so reduce the value of either as to make him appear a gainer when in fact a loser. His returns might be worth twenty per cent. more of corn or hops than his advances, and yet be inferior in general value. The commodity least susceptible of variation in its general value, during short periods, is money; and partly from this circumstance, and partly from its general use as a measure of value, it is the medium in which calculations of profit are usually expressed. But, if considerable periods are to be taken, even money is subject to great variations, and any sudden change in the facility of obtaining it, arising from an increased fertility of the mines, or an increased productiveness of labour, or an abuse of banking or paper currency, or from similar causes operating in an opposite direction, may materially raise or depress the general value of money in any one Country, even during short periods.

The best standard of value for philosophical purposes appears to be the command of labour. In the first place, labour, next to money, is the principal subject of exchange. And, in the second place, labour, as the principal instrument of production, as the only instrument that can be employed at will in the creation of whatever is most wanted, varies less in its general value than any other article of exchange. Money, and the necessaries of life which approach nearest to it, derive in part their steadiness of value from their constant power of commanding labour, a power belonging to no other commodity. Estimated indeed in one class of objects, and it is the class most coveted by man, we mean power and pre-eminence, the value of the command of labour is almost invariable. Two persons who, at different times or in different places, can each command the labour of one thousand average labourers, may indeed enjoy in very different degrees the comforts and conveniences of life; but in power and pre-eminence in their respective Countries they must be nearly on a par. Each must be one man in a thousand. Each must be a thousand times richer than the mass of his countrymen. If two shillings in Hindostan will command as many labourers as twenty in England, a Hindoo with £3000 a year is, generally speaking, as great a man in Hindostan as an Englishman with £30,000 a year in England.

Philosophically, therefore, we think that the value of the capitalist's advances and returns ought to be estimated in their command of labour; popularly, their value is estimated in money; and, as the reciprocal values of money and labour seldom vary much between the times of those advances and returns, the popular mode of estimation is seldom incorrect; and we shall therefore use both indifferently.

Distribution. Wages and profits. Causes regulating the rate of profit.

The great difficulty of the subject arises from the circumstance, that the rate of profit is not the subject of contract, but of experiment, and cannot be ascertained even by an individual, except as to his *past* operations. While a transaction is going on, the capitalist may hope that the value of the returns will exceed the value of the advances; he may hope that the excess will be considerable; but he cannot be certain that there will be any excess at all; that there will not be a positive loss. He may say what his profit *has* been, but not what it *is*. Frequently, indeed, he cannot say what it *has* been. A whole series of mercantile or manufacturing transactions may be so linked together that, after having been apparently profitable for years, they may terminate in ruin.

If, however, we could ascertain the value of the returns in all the transactions in this Country which were concluded in the year ending yesterday; and also could ascertain what was the value of the advances, and the average time for which those advances were made before the returns were received, we should know what was the average rate of profit in this Country during the last year. Suppose this point ascertained, and the result to be, that the average rate of profit on an advance of capital for a year was in this Country during the last year ten per cent., the question recurs, what were the causes which determined it to be ten per cent. rather than five per cent. or twenty per cent.?

It appears to us that it must have depended principally on the previous conduct of the capitalists and of the labourers of this Country; on the value of the capital which at some previous period was appropriated by the capitalists to produce commodities for the use of labourers, or, to use a more concise expression, to produce wages; and the number of labourers whom the previous conduct of the labouring population had caused to exist.

It will be admitted that, in the absence of disturbing causes, the rate of profit in all employments of capital is equal. If we can ascertain, therefore, what are the causes which regulate the rate of profit in any one of the main employments of capital, we may infer that, in the absence of peculiar disturbance, either the same causes, or, causes of equal force, occasion it to be the same in all others We will inquire, therefore, into the causes which regulate the rate of profit in one of the main employments of capital,—the advance of wages to the labourers who are themselves employed in producing wages, *using the word wages to signify commodities for the use of the labouring population.*

Causes regulating the rate of profit.

To simplify the question, we will suppose a small colony settled in a district where there is abundance of fertile land, and protected by situation and character from external and internal violence, so that neither rent nor taxation need be supposed to exist: we will suppose it to be inhabited by ten capitalists and one thousand two hundred labouring families; *that the use of money is unknown;* that all the buildings, the clothes, the furniture, and the food, in fact, the whole consumption of the people, is consumed in one year and reproduced in the next; that each family receives its wages for the year on the first day of the year, and completes its production on the last day, so that all the advances are made on the first day of the year, and all the returns received on the last day; and that, at the time when the situation of the colony was first noticed, each capitalist had in his possession wages for one hundred and twenty families during a year, the produce of the labour of one hundred families during the previous

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year, (being his capital, and which, to reduce it to one denomination, we will call one thousand quarters of corn;) and commodities for his own use, which we will call twenty casks of wine, the produce of the labour of twenty families during the previous year; (being the stock reserved for his own consumption.)

Under such circumstances, if each capitalist should employ his capital in setting one hundred families to work to reproduce wages, and twenty more to reproduce commodities for his own use, and the labouring population should neither increase nor diminish, the rate of profit would remain stationary at twenty per cent. per annum. The advances every year would be one thousand quarters of corn, being wages produced by the labour of one hundred families, and commanding the labour of one hundred and twenty; the returns would be a stock of wages commanding the labour of one hundred and twenty families during the next year, which would be, in fact, a reproduction of the previous capital of one thousand quarters, and also a stock of commodities for the capitalist's own use, produced by one-sixth of the labour employed in reproducing the capital, and therefore one-sixth of the value of the capital. The value of the returns on an advance of capital for a year would exceed the value of the advances by one-sixth. The rate of profit therefore would, as we said before, remain stationary at twenty per cent. per annum. And five-sixths of the labourers would be employed in producing commodities for their own use, and one-sixth in producing commodities for the use of the capitalists.

We will now consider the effects of any alteration in the proportion of capital to labour. Suppose that emigration or an unhealthy season should diminish by fifty the number of labouring families: each capitalist would have the same capital; consisting of wages produced by the labour of one hundred families during the year, and which we have called one thousand quarters of corn: but the number of labourers being diminished by one-twenty-fourth, instead of commanding the labour of one hundred and twenty families, they would command the labour of only one hundred and fifteen. The one thousand quarters of corn would be divided among one hundred and fifteen families instead of among one hundred and twenty, and the capitalist would get only fifteen casks of wine during the subsequent year instead of twenty. To take the converse: if immigration or an increase of population should have increased the number of labourers by fifty, each capitalist, instead of one hundred and twenty families, would be able to command the labour of one hundred and twenty-five. The one thousand quarters would be divided among one hundred and twenty-five families, instead of among one hundred and twenty, and the capitalist might employ twenty-five families to produce wine for himself instead of twenty. In the one case, profits rise from twenty to about twenty-five per cent.; in the other, they fall to about fifteen. On the other hand, if we suppose the labouring population to remain stationary at one thousand two hundred families, but the capitalists, instead of employing each one hundred families in the production of wages, and twenty in the production of profits, to employ each one hundred and five in the production of wages, each capitalist would at the end of the year have a capital of one thousand and fifty quarters produced by the labour of one hundred and five families, and commanding the labour of one hundred and twenty; or if they each employed in the production of wages only ninety-five families, and in the production of profits twenty-five, each would have at the end of the year a capital of nine hundred and fifty quarters, produced by the labour of ninety-five families, and commanding the labour of one hundred and twenty. Profits would fall in the first instance from twenty per cent. to less than fifteen; in the second, they would rise to more than twenty-five. If, however, the increase of the number of labourers employed in the production of wages should be accompanied by a proportionate increase in the whole number of labourers; or if, when the number of labourers employed in the production of wages was diminished, the whole number of labourers should be diminished in proportion; or, in other words, if the proportion of capital to labour remained unaltered, the rate of profit would be also unaltered. If each were increased, or each diminished, but in different proportions, profits would rise or fall according to the relative variations in the supply of wages and labour.

It appears, therefore, that, under the most simple state of circumstances, the rate of profits depends, as we said before, on the previous conduct of the capitalists and the labourers in a Country.

In this hypothesis we have supposed all the capitalists to act together. And as every permanent increase of capital while the number of labourers remained the same would, under the supposed circumstances, occasion a proportionate diminution of the rate of profit, it never could be the interest of the capitalists, as a body, to increase their capital, except with a view to increase the number of labourers; or even to keep up their capital, except so far as it should be necessary to keep up the existing number of labourers. It would be their interest, if the population were incapable of increase, to devote to the production of wages labour just sufficient to produce the necessaries of life for that stationary population, if the population were advancing just sufficient to enable it to advance; to treat the labourers, in short, as a farmer treats his horses, or a slave-owner his slaves.

Under such circumstances, supposing the capitalists to be governed solely by their interest, the rate of profit would depend partly on the productiveness of labour, and partly on the period that must elapse between the time of the advances and of the returns. Given the period of advance, it would depend on the productiveness of labour. If a labourer by a year's labour could produce a return which, to reduce it to one denomination, we will call ten quarters of corn, and five quarters were enough for his support, the rate of profit would be one hundred per cent. per annum. By an advance of five quarters the capitalist would obtain a return of ten. If the labourer could produce fifteen, the rate of profit would be two hundred per cent.; by an advance of five the capitalist would obtain fifteen. If the labourer could produce only seven and a half, profits would be fifty per cent. On the other hand, the productiveness of labour being given, the rate of profit would depend on the period for which the capital must be advanced. When the labourer receiving five quarters as wages could, by a year's labour, produce ten, a capitalist with a capital consisting of ten quarters could employ two labourers, each of whom would return to him ten quarters every year. But if, instead of returning ten quarters at the end of one year, a labourer returned twenty quarters at the end of two years, a capitalist with a capital of ten quarters would be able to employ only one labourer instead of two; for if he were to employ two his capital would be exhausted before it was repro-

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duced. Only one-half of the number of labourers could be employed by the same amount of capital, and instead of getting a net revenue of ten quarters every year, the capitalist would get a net revenue of only ten quarters every two years.

Happily, however, the capitalists of a Country do not act as a body. Each pursues his own scheme of aggrandizement, indifferent to its effect on his neighbours, and it is chiefly to their mutual competition that we owe the increase both of capital and of population. To revert to our original hypothesis; suppose one of the capitalists, instead of employing, like each of the others, twenty labourers to produce commodities for his own use and one hundred to produce wages, to employ one hundred and ten labourers in the production of wages. At the end of the year he would have a capital consisting of one thousand one hundred quarters of corn produced by the labour of one hundred and ten families, and commanding, *at the existing rate of wages*, the labour of one hundred and thirty-two families; and the nine others would have each a capital consisting of one thousand quarters, produced by the labour of one hundred families, and commanding, *at the existing rate of wages*, one hundred and twenty families. The whole capital of the Country, instead of its former amount, namely, ten thousand quarters, being wages for one thousand two hundred families, would amount to ten thousand one hundred quarters, being wages for one thousand two hundred and twelve families. But as there would be only one thousand two hundred families to receive them, profits would fall about one per cent., or from twenty per cent. to a fraction less than nineteen per cent. per annum. This fall of profits would prevent the capitalist to whose conduct it was owing from reaping the full benefit of his accumulation. He would find himself possessed of a capital consisting of one thousand one hundred quarters, being wages produced by the labour of one hundred and ten families, and commanding the labour of one hundred and thirty and a fraction; but every other capitalist would find his capital of one thousand quarters, produced by the labour of one hundred families, commanding the labour of a small fraction less than one hundred and nineteen families. The first, or accumulating capitalist, would find the value of his capital and the amount of his profits increased, though the rate of profits had fallen one per cent. But all the other capitalists would find both the value of their capital and the amount of their profits diminished.

Now there is nothing to which a capitalist submits so reluctantly as the diminution of the value of his capital. He is dissatisfied if it even remain stationary. Capitals are generally formed from small beginnings by acts of accumulation, which become in time habitual. The capitalist soon regards the increase of his capital as the great business of his life; and considers the greater part of his profit more as a means to that end than as a subject of enjoyment. It is probable, therefore, that the other capitalists in the Country would endeavour to keep the value of their capitals unimpaired, though at the expense of a diminution of the general rate of profit. One after another would follow the example of the first-mentioned capitalist, and devote to the increase of their respective capitals a portion of the labour previously employed in furnishing commodities for their own use. In time each capitalist, instead of employing one hundred families in the reproduction of capital, and twenty in supplying his own enjoyments, would employ one hundred and ten in the reproduction of capital, and only ten for his own purposes. The rate of profit would fall from twenty to ten per cent., and, of the one thousand two hundred labouring families, one thousand one hundred would be employed in producing wages, and only one hundred in producing profits. The annual produce of the Country, instead of ten thousand quarters of corn and two hundred casks of wine, would consist of ten thousand one hundred quarters of corn and one hundred casks of wine. Instead of five-sixths of the labourers in the Country being employed in producing commodities for the use of the labourers, and one-sixth for the use of capitalists, eleven-twelfths would be employed for the benefit of the labourers, and only one-twelfth for the benefit of the capitalists.

This fall of profit, however, could take place only on the supposition of the number of labouring families remaining unaltered. But it is highly improbable that it could remain unincreased. The increase of wages would enable the labourers to marry earlier, or to raise more numerous families. If labour should remain equally porductive, their numbers might increase until the former proportion of labourers to capital had been restored. All the results would be beneficial. The labourers would not be worse off than before the additional accumulation took place, and the capitalists would be better off. The value of their capitals and the amount of their profits would be increased, and the rate of profit would be again twenty per cent. per annum.

We set out with supposing a Country possessing an abundance of fertile land. Under such circumstances the productiveness of labour might for a long period continue, or even increase, with every addition to the number of its inhabitants. But in a densely-peopled Country the powers of labour seldom remain the same during an increase of population. In manufactures labour becomes proportionably more productive. In agriculture, unless aided by increased industry or skill, or by permanent improvements of the soil, it becomes proportionably less so. And, as the labourer consumes chiefly raw or slightly-manufactured produce, the increased facility of obtaining manufactures may not make up for an increased difficulty in obtaining raw produce. In an old Country, therefore, when the rate of profit has been reduced by an increase of capital, it seldom can be fully restored by a proportionate increase of population, unless either the labourer receives a smaller quantity of raw produce than before, or the necessity of cultivating lands of inferior productiveness is obviated either by permanent improvements, such as draining marshes or fertilizing bogs, or by additional industry or skill, or by the importation of raw produce. In such Countries the natural progress seems to be an increase of capital, occasioning a fall of the rate of profit; a check to that fall, occasioned by an increase of the labouring population; a check to that increase, occasioned by an increased difficulty in obtaining raw produce; and a diminution, rarely amounting to a removal, of that difficulty, occasioned by permanent agricultural improvements, increased industry or skill, or foreign importation; leaving, as the general result, a constant tendency towards an increase of capital and population, and towards a fall in the rate of profits.

In our hypothesis we have supposed the whole capital of the Country to be consumed and reproduced every

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year. Under such circumstances it has appeared that, the number of labourers remaining the same, no permanent addition could be made to capital without occasioning immediately a proportionate diminution of the rate of profit, since that addition would disappear in a year unless reproduced by a repetition of the sacrifice on the part of the capitalist by whom it was originally created. But the result would be different if that addition were made in a form requiring no further labour for its reproduction. Suppose the capitalist, instead of adding five to the hundred families employed in producing wages, were to employ the additional five in the construction of a durable machine enabling one man to do some piece of work that previously required two. At the end of the first year each capitalist would possess wages for one hundred and twenty families, produced by the labour of one hundred families; commodities for his own use, produced by the labour of fifteen families; and his machine, produced by the labour of five families. But in every subsequent year he might obtain wages for one hundred and twenty families by employing only ninety-nine families and his machine, and might employ twenty-one families in producing commodities for himself. Both the rate and the amount of profit would be increased without any diminution of wages. Such a machine is a new labourer added to the existing number of labourers, but a new labourer whom it costs nothing to maintain. It adds to the amount of the profit of the capitalist who has constructed it, without either taking from the profits of other capitalists, as must be the case when additional capital is created, which must be kept up and worked by additional labour; or taking from the wages of the other labourers, as must be the case when an additional labourer is added, whose subsistence must be taken from the common fund. A machine or implement is, in fact, merely a means by which the productiveness of labour is increased. The millions which have been expended in this Country in making roads, bridges, and ports, have had no tendency to reduce either the rate of profit or the amount of wages. They have, in fact, had a tendency to keep up both, by enabling labour to be more productive, and consequently enabling the circulating capital and the population of the Country to increase in corresponding ratios.

It appears, therefore, that in one of the main employments of capital, namely, the employment of labourers to produce commodities for the use of labourers, or, in other words, to produce wages, the difference between the value of the returns and the value of the advances depends on the amount of labour which at a previous period was devoted to the production of wages, compared with the amount of labour which those wages when produced can command. And as the rate of profits in every different employment of capital has a tendency to equality, we may infer that all capitals, however employed, yield about the same rate of profit as those which are employed in the production of wages.

Average period of advance of capital.

The first of the two principles which regulate the division of the produce between the capitalist and the labourer, namely, the rate of profit in the advance of capital for a given time, having been, in some measure, ascertained, we proceed to inquire into the causes which regulate the second principle, namely, the average time for which the capital must be advanced.

It must be recollected, however, that the expression "the capitalist's share," though familiarly used by Economists, is not strictly correct. When the product is completed, it is the sole property of the capitalist, who has purchased it by paying in advance the labourer's wages. What is meant, therefore, by "the capitalist's share," is that portion of the product, or of the price for which it sells, which the capitalist can retain and apply for his own purposes, keeping the value of his capital unimpaired. What is meant by "the labourer's share" is that portion of the produce, or of the price for which it sells, which the capitalist, if he keep his capital unimpaired, cannot employ for his own purposes, but must employ in advancing the price of the labour by which the work of reproduction is to be performed. We have already shown that, the period of advance being given, these proportions are determined by the rate of profit. It is equally clear that, the rate of profit being given, they must be determined by the period of advance. If a capitalist has a return which we will call twelve quarters of corn, and we wish to know how much of it he must retain as capital, and how much he may use as profit, the first inquiry is, for what period must he advance his capital before he can again obtain a similar return? The next inquiry is, what is the current rate of profit? If the answer to the first inquiry be, one year, and to the second, twenty per cent. per annum, it follows that, by constantly employing ten quarters as wages, he will receive two as profit. If the period of advance be only six months, the rate of profit continuing at twenty per cent. per annum, he must employ eleven and a fraction as capital, and will not receive quite one as profit. If the period of advance be two years, the rate of profit continuing at twenty per cent. per annum, rather less than eight quarters will form a sufficient capital, and rather more than four will be profit. With every prolongation of the period of advance, the rate of profit continuing the same, the capitalist's share must increase. With every abridgement of that period it must diminish. And it is equally obvious that, the period of advance being given, the capitalist's share must augment with every increase of the rate of profit, and diminish as that rate decreases.

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On what then does the period for which capital is to be advanced depend? To this question no general answer can be given. The period differs according to the accidents of soil and climate; it varies indefinitely in every different business, and even in employments which, in other respects, are perfectly similar.

In Europe the harvest is annual; in Hindostan it recurs every six months. The average period for which agricultural wages are advanced must be at least twice as long in Europe as in Hindostan. A great part of the capital employed in breeding horses must be advanced four or five years; that employed in planting must be advanced forty or fifty. A very small part of the capital of a butcher or a baker is advanced for more than a week. The stock of a fishmonger spoils in a day; that of a Rhenish wine-merchant is improved by being kept a century. As a general rule, the average period is longer or shorter in one Country than in another in an inverse proportion to the general rate of profit. In the general market of the world, a Country in which the rate of profit is low has over one where it is high an advantage which increases at compound interest, as the period of advance is prolonged. The rate of profit in Russia is supposed to be above twice as high as in England. We will suppose that rate to be five per cent. per annum in England, and ten in Russia. A commo-

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dity prod..ced in Russia by an advance of £10 for twenty years would sell for nearly £70. A commodity produced in England by the advance of £20 for the same time would sell for less than £60. The difference in the rate of profit would far outbalance a doubling of the first expenditure. Profits are supposed to be lower in Holland and in England than in any other part of the globe. The English and the Dutch, therefore, have almost a monopoly in those trades in which the returns are distant. Abstinence with them is a cheap instrument of production, and they use it to the utmost. In their commerce with other nations they generally pay in ready money, but give a very long credit. They purchase raw produce, and sell manufactures. In many instances they even advance to the foreign Countries the first expenses of production. The indigo of Bengal, the wines of the Cape, the wool of Australia, and the silver of Mexico, are in a great measure produced by the advance of English capital. The accumulated interest on such advances would be an intolerable addition to the value of the returns if the rate of profit were high. This circumstance occasions a tendency to uniformity in the proportion, in different Countries, in which the produce is shared between the capitalist and the labourer. Where profits are high the capitalist's share is kept down by the shortness of the period for which his capital is advanced. Where they are low it is kept up by the prolongation of that period.

The labourer is far more interested in the comparative rate of profit than in the comparative period for which capital is advanced. The productiveness of labour and the period of advance being given, we have seen that the amount of his share of the product depends on the rate of profit. It is his interest, therefore, in the first place, that when capital is employed *in the production of the commodities which he consumes*, all other things remaining the same, the rate of profit should be low. And if it were possible that the rate of profit in other employments could be higher, capital would be diverted from the only production in which the labourer is directly interested—the production of commodities for his own use—and the general fund for the maintenance of labour would be diminished. All other things, therefore, remaining the same, it is the labourer's interest that the rate of profit should be *universally low*. But it must be recollected, first, that the average period for which capital is advanced, especially in the production of the commodities used by labourers, is so short that the capitalist's share is small even when profits are high: if the advance has been for six months, the capitalist's share, at the high rate of twenty per cent. per annum, would be less than one-eleventh: and, secondly, that a high rate of profit is generally found to accompany a great productivenes of labour. And therefore that, in general, the labourer is better paid, or, in other words, receives a larger amount of commodities, when profits are high, that is when he receives a small share, than when profits are low, that is when he receives a large share, of the value of what he produces. The increase of the labourer's share from ten-elevenths to twenty-one-twenty-seconds, which would be the consequence in the case which we have supposed of a fall of profits by one-half, would add very little to the *amount* of his wages.

On the other hand it is his interest that, when capital is employed in the production of *what he himself consumes*, the period of advance should be short. We will suppose a labourer employed on the least productive soil to produce by a year's labour employed in hoeing and weeding an additional produce of twenty-two quarters of corn; the wages of labour to be £20 a year; the rate of profit to be ten per cent. per annum, and a year to elapse between the advance of the wages and the corn being fit for use; the price of the corn would be £22; the labourer would receive twenty quarters, or, what is the same, £20, with which he could purchase twenty quarters. But if corn were not fit for use until it had been kept for ten years, on the same data, the corn, instead of selling for £22, would sell for above £50; the labourer would receive less than ten quarters instead of twenty, or, what comes to the same, his wages, instead of twenty, would purchase less than ten quarters. To produce the corn would require the same degree of labour as before, but ten times as much abstinence.

Another consequence of the prolongation of the period of advance would be, that with the same amount of capital the capitalist would be able to maintain much fewer labourers than before. If ten quarters were necessary to maintain a labouring family during a year, and they could reproduce eleven in a state fit for consumption at the end of the year, a capital of one hundred quarters would enable a capitalist to keep in constant employ ten labouring families during the first year, and eleven during every subsequent year. But, if the corn were not fit for consumption till the end of ten years, a capitalist starting with a capital of one hundred quarters could not maintain more than a single family. For, if he were to maintain more, the capital would be exhausted before it was reproduced. The prolongation of the period of advance would have precisely the same effect as a diminished productiveness of labour.

But the prolongation of the period of advance of the capital employed in the production of the commodities which the labourer does not consume is utterly indifferent to him. If a labourer by a year's labour can produce twenty-two ounces of lace, his wages being £20 a year, and advanced for a year, and the rate o profit being ten per cent., he will receive ten elevenths of the value of the lace, or, in other words, he might purchase with his wages twenty ounces of lace. If the lace required keeping for ten years, his wages would purchase less than ten ounces of the lace in its complete state. But as he never wishes to purchase lace, and as the prolongation of the period for which capital must be advanced in the production of lace would not affect either the productiveness of labour, or the rate of profit, or the period of advance in any other employment, it would be utterly indifferent to him; it would affect only the consumers of lace.

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We have seen that, although practically high wages and high profits generally go together, yet, all other things remaining the same, it is the interest of the labourers that profits should be universally low. It is equally clear that it is the interest of the capitalists that they should be universally high. A fall in the rate of profit in any one employment has a tendency to force capital into the others. This diminishes the competition among the first-mentioned capitalists, but increases it among the others. The first are relieved, but it is only by the loss being spread over the whole body.

But a prolongation of the period of advance affects the capitalist only so far as he uses the specific commodity with respect to which that prolongation has taken place. The rate of profit on the advance of capital for a given period being given, the length of

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the period between the bottling of a pipe of port and its being fit for use affects a wine merchant only so far as he drinks port. As a consumer, it is his interest that the period should be short; as a capitalist it is immaterial to him.

We have now given an outline of the causes which affect the general rate of wages, the most important and the most difficult of all the subjects embraced by Political Economy. It has appeared, first, that the general rate of wages depends on the amount of the fund for the maintenance of labourers, compared with the number of labourers to be maintained.

Secondly, that the amount of that fund depends partly on the productiveness of labour in the production of the commodities used by the labourer, or, to speak more concisely, in the production of wages, and partly on the number of labourers employed in the production of wages compared with the whole number of labourers.

Thirdly, that the productiveness of labour depends on the character of the labourer, or the assistance he derives from natural agents, and from capital, and on his freedom from interference.

Fourthly, that, in the absence of rent and improper or unequally-distributed taxation, the proportion of the labourers employed in producing wages to the whole number of labourers depends partly on the rate of profit, and partly on the time for which the capital employed in the production of wages must be advanced.

Fifthly, that the rate of profit, at any given time, depends on the previous conduct of capitalists and labourers.

And, sixthly, that the period for which capital must be advanced is subject to no general rule, but has a tendency to be prolonged when profits are low, and shortened when they are high.

The inquiry into the causes which regulate wages has, in a great measure, ascertained those which affect profits. We have to add only that profits may be considered in three points of view: first, as to their rate; secondly, as to their amount; and, thirdly, as to the amount of desirable objects which a given amount of profit will command. The causes which decide the rate of profit have been already considered. It has been shown that they depend on the proportion which the supply of capital employed in providing wages bears to the supply of labour. The rate being given, the amount of the profit received by any given capitalist must depend, of course, on the amount of his capital. It follows that, when the rate of profit falls in consequence of an increase of capital without a proportionate increase of labourers, the situation of the existing capitalists, as a body, cannot be deteriorated, unless the fall in the rate has been so great as to overbalance the increase of the amount. Two millions, at five per cent., would give as large an amount of profit as one million at ten. At seven and a half per cent. they would give a much larger. And such is the tendency of an increase of capital to produce, not indeed a corresponding, but still a positive increase of population, that we believe there is no instance on record of the whole amount of profits having diminished with an increase of the whole amount of capital.

Totally distinct from the amount of profit is the amount of desirable objects which a given amount of profit will purchase. A Chinese and an English capitalist, each of whose annual profit will command the labour of ten families for a year, will enjoy in different degrees the comforts and conveniences of life. The Englishman will have more woollen goods and hardware, the Chinese more tea and silk. The difference depends on the different productiveness of labour in China and in England in the production of those commodities which are used by the capitalists in each Country. In the command of labour, and in the rank in society which that command gives, they are on a par. We have seen that, as population advances, labour has a tendency to become less efficient in the production of raw produce, and more productive in manufactures. The same amount of profit, therefore, will enable the capitalist in a thinly-peopled Country to enjoy coarse profusion, or among a dense population moderate refinement. A South American, with an annual income commanding the labour of one hundred families, would live in a log-house on the skirts of a forest, and keep, perhaps, one hundred horses. An Englishman with the same command of labour would live in a well-furnished villa, and keep a chariot and pair. Each would possess sources of enjoyment totally beyond the reach of the other.

Variations of the Amount of Wages and the Rate of Profits in different Employments of Labour and Capital.

In the previous discussion we have assumed the existence of a certain average rate of wages and average rate of profits. We now propose to consider the influence of some specific causes on the amount of wages and the rate of profits in different employments of labour and capital.

The justly-celebrated chapter on this subject in the *Wealth of Nations* begins with the following words:

"The five following are the principal circumstances which, so far as I have been able to observe, make up for a small pecuniary gain in some employments, and counterbalance a great one in others. 1. The agreeableness or disagreeableness of the employments themselves. 2. The easiness and cheapness, or the difficulty and expense, of learning them. 3. The constancy or inconstancy of employment in them. 4. The small or great trust which must be reposed in those who exercise them. 5. The probability or improbability of success in them." Book i. ch. x.

As our remarks will be chiefly a commentary on those of Adam Smith, we shall, as far as we can, follow his arrangement. We shall begin, therefore, by the influence of agreeableness or disagreeableness.

The act of labouring implies a sacrifice of ease, and it is chiefly to this sacrifice that our attention is directed when we speak of wages as the remuneration for labour. But, as we have already observed, the indolence which generally indisposes to severe or long-continued bodily exertion is not in all cases the only feeling which the labourer has to conquer. His employment may be dangerous, or physically disagreeable, or degrading. In any one of these cases his wages are the reward not only of the fatigue, but of the hazard, the discomfort, or the discredit which he has encountered. Adam Smith, however, has remarked, that the prospect of hazards from which we can hope to extricate ourselves by courage and address is not disagreeable, and does not raise the wages of labour in any employment. "The dangers and hair-breadth escapes of a life of adventure, instead of disheartening young people, seem frequently to recommend a trade to them. But it is otherwise,"

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he observes, "with those in which courage and address can be of no avail. In trades which are known to be very unwholesome the wages of labour are always remarkably high." *

Unwholesomeness, indeed, is generally united to other disagreeable circumstances. Dirt, dust, deleterious atmosphere, exposure to continued heat or cold, or to sudden transitions from the one to the other, which are the principal causes of unhealthiness in any business, are also the principal causes of its being generally disagreeable. When toil, disease, and discomfort, are all to be encountered, the temptation must indeed be high. But this union is not universal. The trade of a house-painter is one of the most agreeable, and one of the most unwholesome, among ordinary occupations. On the other hand, that of a butcher, though brutal and disgusting, is eminently healthy. The wages of each are, we believe, about equal, and considerably exceed the remuneration for the mere labour undergone, which, in fact, is in both cases very trifling. But the fear of popular odium, and, what is always strongest amongst the least educated, the fear of popular ridicule, as they are amongst the most powerful feelings of our nature, are the most effectual means by which the wages of an employment can be increased. To Adam Smith's instance of a public executioner may be added that of a common informer; both of whom are remunerated at a rate quite disproportioned to the quantity of work which they do. They are paid not so much for encountering toil as for being pelted and hissed. The most degrading of all common trades, perhaps, is that of a beggar; but, when pursued as a trade, it is believed to be a very gainful one.

Such appears to be the influence upon wages of danger, discomfort, and disgrace. And it may be supposed that any peculiarly agreeable employment is generally as comparatively underpaid as peculiarly disagreeable ones are overpaid. Adam Smith has accordingly remarked that in a civilized society hunters and fishers, who follow as a trade what other people pursue as a pastime, are generally very poor people. "Fishermen," he observes, "have been poor from the times of Theocritus. The natural taste for these employments makes more people follow them than can live comfortably by them; and the produce of their labour, in proportion to its quantity, comes always too cheap to market to afford any thing but the most scanty subsistence to the labourers." Hunting, however, can scarcely be said to exist as a trade in any well-civilized Country. And we doubt the accuracy of Adam Smith's statement as to fishermen; unless, as perhaps was the case, he intended to confine them to the small number of anglers and poachers on rivers, who do, in fact, follow as a trade what other men enjoy as a pastime. Marine fishery is a business of too much toil and hardship to be very attractive; and if any proof, besides the well-fed persons and ample clothing of the men and their families were required, of its being well paid, it would be found in the fact that the capital employed in it, which is far from inconsiderable, generally belongs to the fishermen themselves.

As a general rule, we fear it must be admitted that the occupations open to those who are not possessed of capital differ only in the degree in which they are disagreeable. The least disagreeable are man's primeval occupations, those of a shepherd and a tiller of the ground. And, accordingly, we believe that in every state of society the lowest wages are those which are paid to agricultural labourers. The current wages of common agricultural labourers may, therefore, in general be considered as representing the value, at the time and place where they are paid, of mere bodily labour. If, at the same time and place, we find the services of any other labourer more highly paid, we may infer either that his employment is subject to some peculiar disadvantage, or that, in fact, rent or profit enter into his remuneration.

Adam Smith states that, in point of agreeableness or disagreeableness, there is little or no difference in the greater part of the different employments of stock, though a great deal in those of labour; and he infers, as we have seen, that average profits are more nearly on a level than average wages. That portion of profit which is simply the remuneration for abstinence is certainly, at the same time and place, nearly on a level; for abstinence, being a negative idea, does not admit of degrees, excepting in the amount of capital from the unproductive use of which the capitalist abstains, and the length of time during which he abstains.

But we cannot admit that the agreeableness or disagreeableness of the greater part of the different employments of capital is about the same. Nor would Adam Smith have stated them to be so unless he had used wages in a wider, and profit in a narrower sense than that which has been adopted in this Treatise. Wages, in the sense in which we have used the word, are paid almost exclusively for undergoing bodily labour or bodily inconvenience, and bodily labour is almost always disagreeable. But the labour of employing capital is principally mental, and mental exertion is often delightful. We frequently hear of men who are devoted to their profession or their business, however generally unattractive. A surgeon once told us that, whatever were his income, his utmost happiness would be to superintend a great military hospital. Half the miseries of mankind have arisen from the delight of statesmen in governing, and of generals in war. Again, the mere labourer receives mere pecuniary wages, or food, shelter, and clothing, of equal value. The capitalist is often paid by power or reputation, and sometimes receives the highest of human rewards, the consciousness that he has been widely and permanently useful. And, on the other hand, there are employments, as for instance the slave-trade, which imply fatigue, hardship, and danger, public execration, and, if a slave-trader can be supposed to reflect on the nature of his occupation, self-reproach. It is unnecessary to prove by a formal induction that, when almost all that renders life agreeable, or even endurable, is sacrificed to profit, the profit must be great; or that competition must reduce very low the pecuniary reward or valuable remuneration of occupations which seem to carry with them their own reward.

It may not appear obvious why the extra profit of a disagreeable employment should bear any proportion to the value of the capital employed in it. It must be remembered that, since the number of persons possessed of a given capital becomes rapidly smaller as the amount of the supposed capital is larger, the possessors of any given amount of capital enjoy a sort of monopoly, which becomes stricter and stricter as the given amount is larger; and, secondly, that the larger a man's capital, and consequently his income, the greater must be the temptation

* Book i. ch. x.

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necessary to induce him to encounter moral or physical evil in the hope of increasing it. On the other hand, both the trouble and the inferiority of rank that accompany any trade are generally in inverse proportion to the capital employed. Where, indeed, the objection to a trade arises from its moral turpitude, as in the case of the keeper of a gambling-house, or of any place of still more shameful resort, its extent will only increase its infamy But in the absence of this peculiar objection, the same trade which on a small scale is mean, is respectable in a large way, and almost dignified when carried to its greatest extent. The trouble cannot be so completely got rid of, but when the capital is large enough to enable the employment of clerks and junior partners of great knowledge and high character, it may often be so far reduced as to occupy a small portion of the principal's daily time. There are at this instant many persons busily engaged, and even distinguished in politics and literature, who are also at the head of great banking, brewing, or mercantile establishments. It is not probable that their occupations in business can employ much of their time.

The result that might be anticipated from these opposing circumstances is, that that part of profit which is the remuneration for the trouble and other sacrifices, independent of abstinence made by the capitalist, though it must positively increase in amount, yet generally bears a smaller proportion to the capital employed as that capital increases in value. And this anticipation is, we think, confirmed by observation. There are, we apprehend, few persons employing in England a capital of £100,000, who would not be satisfied with a profit of less than ten per cent. per annum. A manufacturer of considerable eminence, with a capital of £40,000, complained to us of the smallness of his profits, which he estimated at twelve and a half per cent. About fifteen per cent. we believe to be the average that is expected by men with mercantile capitals between £10,000 and £20,000. Scarcely any wholesale trade can be carried on with a capital of less than £10,000. The capitals of less value, therefore, generally belong to farmers, shopkeepers, and small manufacturers, who, even when their capital amounts to £5000 or £6000, expect twenty per cent., and when it is lower a much larger per centage. We have heard that stall fruit-sellers calculate their gains at 2*d*. in the shilling, or twenty per cent. per day, or something more than 7000 per cent. per annum. This seems, however, almost too low. The capital employed at any one time seldom exceeds in value 5*s*., twenty per cent. on which would only be 1*s*. a day; a sum which would scarcely pay the wages of the mere labour employed. It is, however, possible that the capital may sometimes be turned more than once in a day; and the capitalists in question, if they can be called so, are generally the old and infirm, whose labour is of little value. The calculation, therefore, may probably be correct, and we have mentioned it as the highest apparent rate of profit that we know.

2. Facility of learning the business.

"Secondly," says Adam Smith, "the wages of labour vary with the easiness and cheapness, or the difficulty and expense, of learning the business.

"When any expensive machine is erected, the extraordinary work to be performed by it before it is worn out, it must be expected, will replace the capital laid out on it with at least the ordinary profits. A man educated at the expense of much labour and time may be compared to one of these expensive machines. The work which he learns to perform, it must be expected, over and above the usual wages of common labour, will replace to him the whole expense of his education with at least the ordinary profits of an equally valuable capital. It must do this in a reasonable time, regard being had to the very uncertain duration of human life, in the same manner as to the more certain duration of the machine. The difference between the wages of skilled labour and those of common labour is founded on this principle." Book i. ch. x.

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We agree with the whole of this admirable passage, except that we think it shows the propriety of rather terming the surplus remuneration of skilled over common labour profit than wages. It is an advantage derived by the skilled labourer in consequence partly of his own previous conduct, and partly of that of his parents or friends;—of the labour and of the expense which they respectively contributed to his education. It is profit on a capital, though on that sort of capital which cannot be made available without the labour of its possessor.

Adam Smith has remarked that, in the liberal professions, this labour and expense are very inadequately remunerated; and he attributes the slightness of their remuneration first to the desire of the reputation which attends upon superior excellence in any of them; secondly, to the natural confidence which every man has, more or less, not only in his own abilities, but in his own good fortune; and thirdly, as far as literature and the church are concerned, to the number of persons who are educated for those occupations at the public expense.

The two first causes operate very forcibly. The influence of the third he has, we think, exaggerated, or, perhaps, its force may have much diminished since he wrote. In the first place, though our population has nearly doubled in the interval, the number of provisions for affording gratuitously the means of a liberal education has not materially increased. And, secondly, from the change which has taken place in the style of living at the places of education, and in many cases from the nominal value of the provisions having remained unaltered, while money has lost more than half its value, these provisions now afford much less real assistance to the persons who obtain them. Adam Smith seems to have supposed that the greater part of the clergy were educated at the expense of the public, and he expressly states that few were educated altogether at their own. But at present there are scarcely any undergraduates at either of our Universities wholly maintained by a foundation: probably there are not twenty who receive from such a source one-half of their expenditure, and by far the greater number receive no pecuniary assistance except from the relative cheapness of instruction. We say *relative* cheapness, because the sum of money positively paid for instruction is perhaps as great at Oxford and Cambridge as at most other Universities; but the attention bestowed by the teacher on each individual student is considerably greater. In the foreign Universities a lecture is a discourse delivered by the professor; in ours, the College lectures, which are the principal means of instruction, are, in a great degree, examinations undergone by the pupils. There can be no comparison between the labour imposed on the teacher in these two modes of education. But that which is the laborious one necessarily confines each tutor to a small number of pupils. If our foundations did not afford them an income, our tutors must either require a much larger remuneration from each pupil, or adopt the

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foreign mode of teaching by discourses delivered to large assemblies.

The principal cause which fills the avenues to some of the liberal professions with candidates so numerous as materially to diminish one another's reward is one which Adam Smith has omitted.

The average expense of providing in the cheapest manner for the maintenance of a child until it can maintain itself by ordinary labour may perhaps amount to about £40. This is double the sum for which a parish will indemnify the father of a bastard. The parish, however, speculates on the chances of the child's death. The average expense of giving to a gentleman's son the education which is essential to his holding his father's rank cannot be estimated at less than £2,040. But neither the labour which the boy undergoes, nor the expense borne by his father, is incurred principally in order to obtain future profit. The boy works under the stimulus of immediate praise or immediate punishment. It never occurs to the father that it would be cheaper to have his child nursed in the country at 2s. a week till he is eight years old, and then removed to a farm-yard or a cotton-mill; and that in giving him a more expensive education he is engaging in a speculation which is likely to be unprofitable. To witness a son's daily improvement is, with all well-disposed men, or rather with all men, except a few outcasts, one of the greatest sources of immediate gratification. The expense incurred for that purpose is as much repaid by immediate enjoyment as that which is incurred to obtain the most transitory pleasures. It is true that a further object may also be obtained, but the immediate motive is ample.

But the extra expense and labour thus incurred in some cases constitute the whole expense and labour of preparation for a liberal profession, and in all cases constitute the bulk of that expense and labour. In the church they constitute the whole of the expense, and almost all the labour. A graduate of Oxford or Cambridge may have a very little more to read before he takes orders, but has absolutely nothing more to pay. What he obtains, therefore, as a clergyman, after deducting the mere wages of his additional labour, is pure gain. And when we consider how many are the motives for undergoing that labour, besides the merely pecuniary ones, we might be tempted to wonder that the pecuniary rewards should remain so high. Three circumstances keep them up: two by diminishing the number of candidates, and the third by raising the fund applicable to their use. The two former ones are the indelibility of the clerical character, and the interdiction of clergymen from almost all secular employments, especially from those which offer the most glittering rewards. Many men would enter the church if they could combine it with other occupations, or if they might quit it at pleasure, who refuse to enter into a path in which it is not permitted to turn back or to diverge. These are probably the principal causes which tend in this Country to keep down the number of clergymen. The revenue of the existing members is kept up by means of the fund set apart by law for their use, and somewhat equalized by the repeated intervention of the Legislature to raise the remuneration of curates by prohibiting the incumbent from offering, and the curate from accepting, a stipend as low as would have been fixed on mere principles of competition. The expense of entering the army is probably about equal to that of the church; for though about £600 is to be added for the price of the first commission and for outfit, the difference is about made up by the early age at which the profession can be begun. The expense of the navy is much less, and either profession may be entered upon without further preparatory study. The Legislature has fixed the pay and other advantages of the army and navy (moderate as they appear to be) much higher than would have been necessary to keep up the supply of qualified candidates. The difficulty of obtaining permission to enter either of them is so notorious, that few persons without considerable interest ever think of them. Yet, notwithstanding the influence of this feeling in diminishing the number of competitors, the Admiralty and the Horse Guards are besieged by candidates for first commissions ten times more numerous than the vacancies.

The same may be said of what are the subjects of almost a distinct profession, public offices. Small as the emoluments are, if they are to be considered as repaying the expenses of education, they are objects of eager competition.

If further proof were wanted that the number of the candidates for the liberal professions is principally kept up by the feeling which forces every parent to endeavour to give to his children at least the education of his own rank rather than by calculation, it may be found in the abundance of governesses. The expense of giving to a girl the education which will fit her to be a governess, though not quite equal to that of educating a boy as a gentleman, is yet very considerable: no part of it is ever supplied by the public; and yet that profession is so overstocked with candidates that the pay scarcely equals that of a servant.

An expense of nearly £1000 beyond the common expense of a regular education may be necessary to start a young man as a physician, and perhaps nearly £1500 as a barrister. The lower branches of the legal and medical professions are about as expensive as the church or the army. But no branch of either law or physic admits of practice till after an apprenticeship of from three to five years, or of success, without three or four years of diligent study. The effect of all these causes has been so much to diminish the number of competitors in the medical and legal professions, that we much doubt whether they are now, as Adam Smith states them to have been in his time, under-recompensed in point of pecuniary gain. We speak more doubtfully as to medicine; but we can say, from the observation of many years, that his statement that, "if you send your son to study the law, it is at least twenty to one if he ever makes such proficiency as will enable him to live by the business," has no resemblance to the existing state of things. We have watched the progress of perhaps a hundred legal students, and, where fair diligence has been employed, success has been the rule, and failure the exception. Many, indeed, have not applied fair diligence: but we have seen much more success among the idle than failure among the laborious. So far from the chances being twenty to one *against* a young lawyer, we should be inclined to rate them at two to one in his favour.

3. Constancy or inconstancy of employment.

A third cause of variableness both in wages and in profits is constancy or inconstancy of employment. The variations which it occasions are, however, rather apparent than real. A London porter, employed for an hour, would think himself ill paid by less than a shilling. A pavior or a hodman, whose labour is much more severe, seldom receives more than 3*d*. an hour. But the pa-

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vior can always find a market for his services. At 3*d.* an hour, he can at an average earn three shillings a day, or about £46 a year. The porter may be sometimes a day without a job. If his employment be less regular by three-fourths than that of the pavior, to make his annual wages equal, his hourly wages must of course be three times as high. Adam Smith, indeed, thinks that his annual wages ought to be higher than the average, to make him some compensation for those anxious and desponding moments which the thought of so precarious a situation must sometimes occasion. But this evil is compensated, and, in most dispositions, more than compensated, by the diminution of his toil. We believe, after all, that nothing is so much disliked as steady, regular labour; and that the opportunities of idleness afforded by an occupation of irregular employment are so much more than an equivalent for its anxiety as to reduce the annual wages of such occupations to below the common average.

In the employment of capital, however, this compensation does not often exist. The occasional unproductiveness of his capital, generally speaking, affords no relief to the capitalist. It must, therefore, be compensated by a surplus profit, when productive, at least enough to balance its periods of unproductiveness. A house-builder's capital often lies unproductive; there are some places in which the majority of the houses are unoccupied for nine months in the year. The builder's profit during their occupation must be at least four times as great as if they were regularly inhabited. One of the consequences of the effect of irregularity of employment on wages and profits is to occasion many services and commodities to cheapen as the demand for them increases. A man who can count on employment for four hours a day would be forced by competition to sell his services for nearly half of what he might have asked if he could have reckoned on only two hours. Prices in a watering-place always fall as the season becomes longer.

4. Trust.

The fourth cause assigned by Adam Smith for the variation in wages, the small or great trust which must be reposed in the workman, appears to be in a great measure included in the second of his causes, the expense of education. Occasionally, indeed, we see persons receiving and deserving confidence though brought up under disadvantageous circumstances. The integrity of such persons must arise from a peculiarly happy natural disposition, and its reward may then be considered a species of rent; but, as a general rule, trustworthiness is the result of early moral cultivation, and in that case is as much to be considered a part of a man's immaterial capital as his prudence or his knowledge.

5. Probability of success.

The last of the causes mentioned by Adam Smith, as affecting the remuneration of different employments, is the probability or improbability of success.

Uncertainty of success, in some respects, resembles inconstancy of employment. A few examples will show them to be different. The legal and medical professions are generally thought to be remarkably uncertain, but the employment of a successful physician or barrister is painfully incessant. On the other hand, a man may be morally sure that in a given occupation he will have a day's work forty or fifty times during a year, and that his earnings on those occasions will supply well his annual subsistence. Such an occupation would be certain, notwithstanding its inconstancy.

Uncertainty of success cannot well affect the wages of common labour, since no man, unless he be to a certain extent a capitalist, unless he have a fund for his intermediate support, can devote himself to an employment in which the success is uncertain. But its apparent, and indeed its real effect on *profits*, is very considerable.

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Perfect knowledge, of course, excludes the idea of chance; but if all men had sufficient information to enable them to calculate fairly the chances of success, and were subject neither to rashness nor to timidity, it appears clear that even then the average profits of any employment would be raised by uncertainty of success.

When the sums are equal, to lose is obviously a greater evil than to gain is a good. If two men, with each a capital of £2000, toss up for £1000, the gainer augments his fortune by only one-third, and the loser sacrifices one-half. Laplace calculates the disadvantage at twenty-six per cent. At an equal game, he observes, the loss is relatively greater than the gain. Suppose a player with a fortune of 100 francs to risk 50 of them at heads and tails, his fortune, after he has deposited his stake, will be reduced to 87 francs; that is to say, 87 francs unhazarded would procure him as much happiness as 50 unhazarded, with 50 more subjected to the chance of being doubled or lost. Admitting this calculation to be correct, and admitting the existence of the degree of information and prudence which we have supposed, no one possessed of £10,000 would venture £5000 with an even chance of losing it, unless he had an even chance of gaining not merely £10,000, and an adequate profit on his capital of £5000, but could reckon on a further profit of £1300, as the price for undergoing the risk.

It is needless to say that men are far from possessing this degree either of information or of prudence. It is to be observed, however, that there are two sorts of uncertainty. In some cases the hazard is essentially connected with the employment itself, and recurs, in about an equal degree, at every operation. Smuggling, and the manufacture of gunpowder, are instances. Experience and skill may somewhat diminish the risk; but the best smuggler, and the best maker of gunpowder, probably each, suffers an average amount of loss. But there are employments in which success, if once obtained, is permanent. Such is often the case in mining. That mining is generally the road to ruin is notorious in all mining countries; but there are miners who have never suffered a loss. The same may be said of the liberal professions. Granting them to be as uncertain as Adam Smith believed them to be, the evil to which that uncertainty refers is experienced only by those who fail. To those who succeed they afford a revenue eminently safe and regular. Their uncertainty is personal. It arises from the error to which every man is subject when he compares his own qualifications with those of his rivals. If he be found on the actual trial inferior, his failure is irretrievable. In the other alternative his success is as permanent. Where any business is necessarily and permanently hazardous, the fortunes of any one individual engaged in it afford a sample from which we may estimate the fortunes of all. If only one old farmer could give to us all his personal experience, we should probably have a tolerably correct conception of the hazards to which farming is exposed. But, if we were to estimate the chances of legal or medical success from the average of ten or twenty selected instances, we should be likely to be grossly

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misled. The first sort of uncertainty, therefore, is likely to be estimated with a much greater approach to correctness than the second.

Adam Smith believed both to be under-estimated, and, consequently, that the average profits of all hazardous employments are below the average profits of safe ones. His views are stated with so much force and ingenuity, that we will extract them at considerable length.

"The overweening conceit which the greater part of men have of their own abilities is an ancient evil remarked by the philosophers and moralists of all ages. Their absurd presumption in their own good fortune has been less taken notice of. It is, however, if possible, still more universal. There is no man living who, when in tolerable health and spirits, has not some share of it. The chance of gain is by every man, more or less, overvalued; and the chance of loss is by most men undervalued; and by scarce any man, who is in tolerable health and spirits, valued at more than it is worth.

"That the chance of gain is naturally overvalued we may learn from the universal success of lotteries. The world neither ever saw, nor ever will see, a perfectly fair lottery, or one in which the whole gain compensated the whole loss, because the undertaker could make nothing by it. In the state lotteries the tickets are really not worth the price which is paid by the original subscribers, and yet commonly sell in the market for twenty, thirty, and sometimes forty per cent. advance. The vain hope of gaining some of the great prizes is the sole cause of this demand. The soberest people scarce look upon it as a folly to pay a small sum for the chance of gaining £10,000 or £20,000, though they know that even that small sum is perhaps twenty or thirty per cent. more than the chance is worth. In a lottery in which no prize exceeded £20, though, in other respects, it approached much nearer to a perfectly fair one than the common state lotteries, there would not be the same demand for tickets. In order to have a better chance for some of the great prizes, some people purchase several tickets, and others small shares in a still greater number. There is not, however, a more certain proposition in Mathematics, than that the more tickets you adventure upon, the more likely you are to be a loser. Adventure upon all the tickets in the lottery, and you lose for certain; and the greater the number of your tickets, the nearer you approach to this certainty.

"That the chance of loss is frequently undervalued, and scarce ever valued more than it is worth, we may learn from the very moderate profit of insurers. In order to make insurance either from fire or sea risk a trade at all, the common premium must be sufficient to compensate the common losses, to pay the expenses of management, and to afford such a profit as might have been drawn from an equal capital employed in any common trade. The person who pays no more than this evidently pays no more than the real value of the risk, or the lowest price at which he can reasonably expect to insure it. But, though many people have made a little money by insurance, very few have made a great fortune: and from this consideration alone it seems evident enough that the ordinary balance of profit and loss is not more advantageous in this than in other common trades, by which so many people make fortunes. Moderate, however, as the premium of insurance commonly is, many people despise the risk too much to care to pay it. Taking the whole kingdom at an average, nineteen houses in twenty, or rather perhaps ninety-nine in a hundred, are not insured from fire. Sea risk is more alarming to the greater part of people, and the proportion of ships insured to those not insured is much greater. Many sail, however, at all seasons, and even in time of war, without any insurance. This may sometimes, perhaps, be done without any imprudence. When a great company, or even a great merchant, has twenty or thirty ships at sea, they may, as it were, insure one another. The premium saved upon them all may more than compensate such losses as they are likely to meet with in the common course of chances. The neglect of insurance upon shipping, however, in the same manner as upon houses, is, in most cases, the effect of no such nice calculation, but of mere thoughtless rashness and presumptuous contempt of the risk. The ordinary rate of profit always rises, more or less, with the risk. It does not, however, seem to rise in proportion to it, or so as to compensate it completely. Bankruptcies are most frequent in the most hazardous trades. The most hazardous of all trades, that of a smuggler, though, when the adventure succeeds, it is likewise the most profitable, is the infallible road to bankruptcy. The presumptuous hope of success seems to act here as upon all other occasions, and to entice so many adventurers into those hazardous trades, that their competition reduces their profit below what is sufficient to compensate the risk. To compensate it completely, the common returns ought, over and above the ordinary profits of stock, not only to make up for all occasional losses, but to afford a surplus profit to the adventurers of the same nature with the profits of insurers. But if the common returns were sufficient for all this, bankruptcies would not be more frequent in these than in other trades." Book i. ch. x.

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Whether Adam Smith's conclusions be true or false, they certainly do not follow from his premises. Bankruptcies might be frequent in a trade of extraordinary profit. We will suppose ten merchants each to employ for a year a capital of £10,000 in a remarkably safe trade, and ten others to employ equal capitals for the same period in a hazardous trade; and ten per cent. per annum to be the average rate of profit in undertakings involving similar trouble. The capital of £100,000 engaged in the safe trade would, at the end of the year, be raised to £110,000, but be distributed in the same proportions as before. If the capital engaged in the hazardous trade were also, at the end of the year, to amount to £110,000, it is clear that each trade would have been equally profitable, although a different distribution of the capital might have ruined some, and made the fortunes of others, among the merchants engaged in it. Two might have lost, and two others might have doubled, their whole property. If the capital in the hazardous trade were found, at the end of the year, to have been raised from £100,000 to £120,000, it is clear that the hazardous trade must have been twice as profitable as the safe one, though the whole of the advantage might have fallen to two or three or even to one of the supposed ten merchants, leaving all the others to bankruptcy.

Insurance was a still more unfortunate source of argument; for all the premises that it affords lead to a conclusion directly opposed to Adam Smith's. Insurance is one of the safest of employments. If its profits be remarkably moderate, their moderation can be accounted for only by the extra competition which its safety invites.

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It affords, therefore, at least one example in favour of the superior profits of hazardous employments. Nor can it be said that the majority of persons despise the risk too much to secure themselves against it by paying a moderate premium. So much do they fear the risk that they are willing to guard against it by paying a most immoderate premium. The sum received by the insurance office must, as Adam Smith has remarked, exceed the value of the risk by an amount sufficient to pay the expenses of management, and afford ordinary profit. The sum received by the office on common insurances against fire is 1*s.* 6*d.* per £100; of which at least 6*d.* must go to pay expenses and profit, leaving 1*s.* as the value of the risk. But a duty is also paid to Government by the insured of 3*s.* per £100; so that the whole expense of insurance is 4*s.* 6*d.* per £100, or nearly five times the value of the risk. And, even at this extravagant rate, we believe that of good houses not one in a hundred is uninsured. So little do people despise the risk that, with their eyes open, they purchase a security against it at nearly five times its real value.

We suspect the fact to be that the imagination is unduly affected by the prospect either of enormous gain or of enormous loss; and, consequently, that men are ready to purchase the chance of obtaining a very great advantage, or the certainty of not suffering a very great disadvantage, at a price far beyond the value of either contingency. And this appears to be sufficiently proved by the facts which have been stated respecting insurance and lotteries. The English state lotteries of late times, indeed, afforded much more striking proofs of men's tendency to over-estimate the chances of extravagant gain than those which Adam Smith had seen. The tickets were always worth exactly £10 apiece—£10 for each ticket forming always a sum equal to the aggregate amount of all the prizes; the average price of a ticket was from £21 to £24 apiece. Instead of twenty or thirty per cent. the purchasers paid more than one hundred per cent. more than the value of their hope, just as, in the case of insurance, they pay nearly five hundred per cent. more than the value of their fear. The purchasers of tickets seem to have considered the relation between £24 and £20,000, not that between £24 and the one two-thousandth chance of getting £20,000. Just as those who insure their houses compare £2. 5*s.* with £1000 instead of comparing it with the one two-thousandth chance of losing £1000. Adam Smith has well remarked, that if the disproportion between the sum paid and the sum attainable were altered, even though the bargain were rendered more favourable, the competition for it would diminish. No one would buy half the tickets in a lottery, even at £12 a ticket; he would at once see the absurdity of paying £120,000 for an even chance of getting £200,000, though, if a state lottery were now opened, a folly just twice as great in kind would be committed by thousands. So if, instead of one in two thousand, which we believe to be about the present average, one house in ten were annually burned down, and the annual expense of insurance were £22 10*s.* per cent., insurance would diminish, though the terms would be twice as favourable as they now are.

Those employments which offer the possibility of a great return for a small outlay are of the nature of lotteries; and it may be supposed that they attract competition in proportion not so much to the real value of the contingency as to the excess of the possible return over the certain outlay. If that excess be very great, it may be supposed that the number of competitors in proportion to that of prizes will reduce so low the value of each man's contingency as to render such employments on the whole unprofitable. In this Country the church, the army, and the bar, are such employments. They offer prizes that may satisfy to its utmost almost every human desire; and they require, as we have seen, from those who have already received a gentleman's education, a very moderate further outlay: the church and the army scarcely any; the bar perhaps £1500. Under these circumstances, if the number of barristers were not kept down by the necessity of years of irksome study, and the emoluments of the church and of the army and navy kept up by the funds appropriated to their respective use, we have no doubt that the competition in these professions would reduce their average profit far below even its present moderate amount. We often hear proposals for equalizing, or rather for diminishing, the inequality in ecclesiastical preferments. At first sight it appears a waste to pay £20,000 a year to an Archbishop for doing less than is required from the curate of a populous parish with only £100 a year. But if our object were to obtain an expensively educated clergy on the cheapest terms, that object would probably be best effected, not by diminishing, but by increasing, the value of the highest prizes. The revenues of all the English Bishoprics put together fall short of £150,000 a year. This sum, divided among the ten thousand livings, would raise the value of each by £15. Can any one believe that such a change would not diminish the worldly attractions of the church? Nothing sells so dearly as what is disposed of by a well-constructed lottery, and if we wish to sell salaries dearly, that is, to obtain as much work and knowledge as possible for as little pay as possible, the best means is to dazzle the imagination with a few splendid prizes, and, by magnificently overpaying one or two, to induce thousands to sell their services at half price.

We have been told that it was once proposed at Rome, as the easiest mode of constructing a vast dome, to raise a mound of earth of the required shape, and build over it. But the expense of then removing the earth appeared enormous. On the principle which we have endeavoured to illustrate it was proposed that in raising the mound the earth should be irregularly mixed with coins of gold, silver, and copper, amounting in the aggregate to a sum equal to about half the aggregate amount of the wages which it would have cost to remove it by paid labourers, and then to allow the populace to remove it in barrows, without payment. It was supposed that a sufficient number of persons would offer their services, though, in fact, working, in the aggregate, at half price.

We have already expressed an opinion that the bar is better paid than the church, and we attribute this to its being less of a lottery. The expenditure, as we have seen, is far greater, and the prizes, on the whole, are smaller. The learned profession which offers the fewest prizes and requires the largest outlay, that of a schoolmaster, as it ceases to be a lottery, is by far the best paid. There are probably few capitals which in the aggregate yield so certain and at the same time so large a profit.

In some few cases commercial adventures are of the nature of a lottery. Such were the shares which excited the strange fevers of cupidity and speculation which marked the years of 1720 and 1825. Of the thousands who crowded to buy Chili and Peruvian, and Rio la Plata, and Columbian, and Mexican shares, how many

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can be supposed not to have ascertained, but to have endeavoured to ascertain, or even to have thought of ascertaining, the probability of their Company's success? All they knew was that Real del Monte shares, for which £70 had been given, were selling for £1200: and they bought a few shares in other Companies, because, if the speculation succeeded, they might get one thousand per cent., and if it failed they had only lost one or two hundred pounds.

Generally speaking, however, those commercial adventures which offer a large immediate advantage are more in the nature of ordinary gambling than of a lottery. The possible loss often equals or exceeds, and generally bears a large proportion to, the possible gain. The undue hopes and the undue fears, which we have described as excited by the prospect of enormous gain and enormous loss, may now be supposed to balance one another, and to leave room for the action of Adam Smith's principle, an absurd presumption in our own good fortune. If his theory be correct, if every man in tolerable health and spirits have a tendency to miscalculate the chances in his own favour, it must follow that those speculations, which offer a great gain at the hazard of a great loss, invite so much competition as to be, if not positively unprofitable, at least less advantageous than ordinary employments. And we believe such to be the case. Mining and stock-jobbing are employments of capital which offer splendid success at the hazard of ruinous failure. The former employment is notorious not merely as affording less than average profits, but as affording no aggregate balance of profit at all as productive in the aggregate of loss. Knowledge, diligence, capital, all the materials of success, are applied in Cornwall to one of the richest mineral districts in the world, and yet it is supposed that the aggregate price of the whole of the copper and tin annually raised in Cornwall is not equal to the whole of the expense of raising it. A few capitalists, however, make large fortunes, and their success draws on the rest, generally to loss, often to ruin.

Even if speculation in the funds were attended by no expense, it is mathematically certain that it could in the aggregate afford no profit, as what is gained by one must be lost by another. But it is carried on at a very great expense. Every transfer costs a commission of 2*s.* 6*d.* for every £100 stock. A man who annually buys and sells stock to the amount of £800,000, and that is far from a large amount for an habitual speculator, must at an average pay for commission £1000 a year; and that £1000 exactly represents the amount of his annual loss, supposing him to speculate with average success.

On the whole, however, though we attribute something to men's confidence in their superior good fortune, we attribute much more to their confidence in their superior ability. A confidence which, if universal, would, *on the whole*, produce as much miscalculation as the former, but which is not obviously irrational in *each particular instance*, and on that very account is stronger and more general.

The third and last class of the employments of capital which are subject to uncertainty comprises those which are just the reverse of a lottery: those in which the gain is in each instance small, but nearly certain; and the loss great, but highly improbable.

If our theory be correct, this remote contingency of great loss must in general be overvalued, and the capitalist who submits to it must, in addition to the profit which would content him if his business were perfectly safe, receive at an average in the first place an extra profit equal to the risk, and in the second place, a further profit to compensate his anxiety, to compensate the excess of evil occasioned by loss over the benefit that attends on gain, and a still further profit to compensate the undue importance which he is likely to attribute to the chances against him.

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Now this class comprises almost all those employments of capital which, to distinguish them from those attended by extraordinary risk, are generally termed safe. A merchant or a manufacturer who wishes to be safe must in general give up the hope of obtaining great profit by any single transaction. But no productive employment of capital can be *perfectly* safe. A capitalist may, indeed, *lend* his capital to one who wishes to employ it, on receiving a pledge, and the pledge may so much exceed in value the sum lent as to make the loan secure; but the capital itself, if employed, must be risked. Credit must be given, confidence must be reposed in agents, and when every precaution has been taken, an extraordinary season, an unexpected source of supply, a sudden change in foreign or domestic politics, or a commercial panic, may produce ruin out of the best-arranged operations. No man in business can be perfectly sure that in ten years' time he shall not be a bankrupt. If we are right, this risk of enormous loss, when unbalanced by the hope of enormous gain, must be compensated by an extra profit of something more than its value, just as the chance of enormous gain, when not balanced by the fear of enormous loss, is purchased at more than its value; and as the latter class of employments gives a smaller, so the former must give a greater average return than would be afforded by an employment perfectly safe, if any such there be.

Inequalities in wages and profits occasioned by the difficulty of transferring capital and labour from one employment to another.

The inequalities in wages and profits which we have as yet considered arise from causes inherent in the employments themselves which have been the subjects of discussion, and would, generally speaking, exist even if one occupation could at will be exchanged for another. But great inequalities are found which cannot be accounted for by any circumstances leading men to prefer one employment to another, and which therefore continue only in consequence of the difficulties experienced by the labourers and the capitalists in changing their employments.

The difficulty with which labour is transferred from one occupation to another is the principal evil of a high state of civilization. It exists in proportion to the division of labour. In a savage state almost every man is equally fit to exercise, and in fact does exercise, almost every employment. But in the progress of improvement two circumstances combine to render narrower and narrower the field within which a given individual can be profitably employed. In the first place the operations in which he is engaged become fewer and fewer. "In a pin-manufactory," says Adam Smith, "one man draws out the wire, another straightens it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head; to make the head requires two or three distinct operations; to put it on is a peculiar business; to whiten the pins is another; it is even a

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trade by itself to put them into the paper; and the important business of making a pin is in this manner divided into about eighteen distinct operations." In a large manufactory the man who is engaged in one of these operations has little experience in any of the others.

And, in the second place, the skill which the division of labour gives to each distinct class of artificers generally prevents whatever peculiar dexterity an individual may have from being of any value in a business to which he has not been brought up. A workman whose specific labour has ceased to be in demand finds every other long-established employment filled by persons whose time has been devoted to it from the age at which their organs were still pliable and their attention fresh.

Mr. Ewart, one of the many intelligent witnesses examined by the Committee on Artisans and Machinery, is asked:

"Can you state any facts to prove the inefficiency of even the best workmen when they are taken out of the immediate line of their daily business, though in the same trade?"

He replies, "Yes, I can: I should state particularly the case of the clock and watch tool and movement makers in Lancashire; they are considered the best workmen; they use the same sort of tools that the cotton-machine makers use; but they are brought up to no employment but making those clock and watch tools and movements. When those men come to be employed in making cotton machines we find that they have almost as much to learn as if they had never learnt any working in metal at all. We have found them quite insufficient to do any ordinary filing and turning."*

Garnier, in the amusing notes to his translation of Adam Smith, contrasts the comfort of the lower orders in France with the pauperism of England, and ascribes the difference which he discovers to artificial restraints on the circulation of labour in England, and the absence of such restraints in France. "Under a government," he observes, "which does not interfere with the direction of industry, it is impossible that a man in health and strength can be without employment, unless his vices make employment intolerable to him. Let the workman be allowed to choose the market for his labour, and you may be sure that he will find one, and more and more certainly in proportion to the wealth of the Country. The complaint of want of work is the threadbare excuse of the idler who prefers relief to wages. If he were to search for it, he would find it as well as his companions. In France, though our population is one-third more numerous than that of England, and the fund for the support of labour much smaller, the labouring classes are free from want, or even discomfort."†

There can be no doubt that we have among our institutions and our habits much that fetters and misdirects the industry of our labourers; and that these causes frequently occasion, and always prolong, the want of employment to which large portions of our labourers are frequently exposed. We believe, too, that from many of these causes France is comparatively free. The monopolies possessed by towns and by incorporated bodies of artificers, with their oppressive bye-laws and duties, were swept away by the Revolution. Much, however, that is productive of evils similar in kind, still remains. Not long ago the number of butchers in Paris was, by an ordonnance of police, restricted to four hundred. The most important of all employments, that of affording education, is a government monopoly; and the commercial code of France is even worse than our own. If, therefore, the labouring classes of France never suffer from want of employment, they do not owe their immunity to a complete, or even a very considerable, freedom from interference. If their employment be actually more constant than that of our labouring classes, we believe that they owe that constancy principally to the inferior extent of their manufactures, and, what is both the cause and the effect of that inferiority, to a much less subdivision of labour. Less than one-third of the population of England, and more than two-thirds of the population of France, are employed in the cultivation of the soil. We are inclined to think that, notwithstanding this disproportion, the English labouring classes are better fed than the French. But there is no comparison between their respective enjoyment of clothing and other manufactures. The greater part of the coarser manufactures are both cheaper and better in England; while the wages in France, both of manufacturing and agricultural labourers, are about half what they are with us. "A peasant suffering severely from rheumatism," says M. Say, (*Cours Complet*, tome i. p. 46,) "asked my advice. I recommended to him a flannel waistcoat next the skin. He did not know that there was such a thing as flannel. I told him then to wear under his shirt a cloth waistcoat turned inside-out. How, he asked, am I to get cloth to wear under my shirt, when I have never been able to afford to wear it above? And yet he was no worse off than his neighbours."

The French labourer, being employed in more capacities than the Englishman, has more trades to turn to, and for that very reason is less efficient at any one. The Russian is probably more seldom out of employ than the Frenchman, and the Tartar less frequently than either. But few principles are more clearly established than that, *cæteris paribus*, the productiveness of labour is in proportion to its subdivision, and that, *cæteris paribus*, in proportion to that subdivision must be the occasional suffering from want of employment. A savage may be compared to one of his own instruments, to his club, or his adze, clumsy and inefficient, but yet complete in itself. A civilized artificer is like a single wheel or roller, which, when combined with many thousand others in an elaborate piece of machinery, contributes to effects which seem beyond human force and ingenuity, but, alone, is almost utterly useless.

The difficulty in transferring *material* capital from one employment to another depends principally on the degree in which it has been manufactured, and on the change to be made in the disposition of its parts. The destination of raw material can, in general, be changed with little inconvenience. The stones that have been collected for a bridge may easily be employed for a house. But if they have been formed into a house, or a bridge, the value of the materials would scarcely pay the expense of removing them. Those costly instruments which form the principal part of fixed capital can scarcely ever be applied in their original state to any but their original purposes. They are employed, therefore, in the same way, long after they have ceased to afford average profit on the expense of their construction, because a still greater loss would be incurred by attempting to use them in a different manner. It would be a bad speculation to erect a steam-engine at the cost of £20,000 which should

* *Report on Artisans and Machinery*, 1824, p. 251.

† Note 25.

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return an annual profit of only £100, but it would be a still worse one to sell it as old iron for £500.

There is a considerable resemblance in this respect between mental and inanimate capital. Probity, industry, judgment, elementary knowledge, and the other moral and intellectual habits and acquirements to which we give the general name of a "good education," are a kind of mental raw material, of which the destination can be altered at pleasure. The peculiar knowledge and habits of a given profession are like a steam-engine or a water-mill, of comparatively small value for any but their appropriate purposes. In general, however, mental capital is the more transferable of the two, and becomes more and more so the more exclusively it *is* exclusively mental. The professional knowledge and dexterity of a weaver would be of little use to him in any other employment. A lawyer or a physician, prevented by circumstances from continuing to practise, would find the information and the intellectual habits which he had acquired in his former profession of considerable advantage in any new one. Bodily labour, especially when the labourer is confined to a very few operations, so that a few muscles have too much and the rest too little to do, often weakens, and almost always distorts, the frame. Mr. Shaw, a surgeon of great eminence in the treatment of distortion, told us that, as he walked along the streets, he could in general tell each man's trade by his characteristic deformity. But mental exertion, unless in those rare cases in which it is carried to such an excess as to produce cerebral derangement, never seems to weaken the mind. It may sometimes, perhaps, a little distort it, may sometimes give to one or two faculties an undue preponderance; but even this, to such an extent as to diminish the productiveness of the individual's subsequent exertions, is comparatively rare. And, in general, it will be found, that the more work a man's mind has done, the more he is able to do, and the better he will do it.

The obstacles which exist, even within the same neighbourhood and the same Country, to the transfer of labour and capital from one employment to another, are of course aggravated, when not only the occupation but the neighbourhood or the Country is to be changed. Adam Smith states the common price of labour in London and its neighbourhood to have been, when he wrote, 1*s.* 6*d.* a day, and the usual price in the Lowlands of Scotland to have been 8*d.* "Such a difference of prices," he adds, "which it seems is not always sufficient to transport a man from one parish to another, would necessarily occasion so great a transportation of the most bulky commodities, not only from one parish to another but from one end of the kingdom, almost from one end of the world, to another, as would soon reduce them more nearly to a level. After all that has been said of the levity and inconstancy of human nature, it appears evidently from experience, that a man is, of all sorts of luggage, the most difficult to be transported." Book i. ch. vi.

When we compare the wages of labour in different Countries, we usually estimate them in money. And we are forced to do this for two reasons: first, because the precious metals are the only important commodities universally distributed throughout the world; and, secondly, because they are the only commodities of which the value is every where the same, or very nearly the same. We should gain little information by comparing the number of pine-apples that can be earned in Java and in England by a week's ordinary labour. And still less by comparing the quantity of pulque earned by a Mexican with the quantity of whisky earned by an Irishman. But money wages, though they measure accurately the value of national labour in the general market of the world, afford a very imperfect test of the degree of comfort and convenience obtained by the labourer in different Countries. Now it is this difference, not the difference in money wages, that leads him to change his residence; and we can ascertain, or rather approximate to ascertaining, these differences only by translating the money wages in different Countries into the commodities used by the labourer. The money wages of labour in North America are about one-third higher than in England; this is in some measure compensated by the higher price of manufactures. But as food, which every where forms the largest portion of the labourer's expenses, is considerably cheaper than with us, the real superiority of the American over the English labourer is greater than is indicated by the difference in their wages. We are told (Crawford's *Embassy*, p. 468) that a day labourer in Bengal can hardly earn £3 a year. Notwithstanding this low rate of wages, most manufactures are dearer there than in England. Food, of course, is cheaper; for were it at the same price as the cheapest food in England, a family could not exist at about 1*s.* a week. And it is obvious that in every Country the average wages of labour must be sufficient to support an average family. In proportion to the quantity of land and labour required, rice is, perhaps, the most abundant food that the earth affords. Rice, therefore, is the food of the Bengallee, and his wages, supposing them to be all laid out in food, would produce him about eight hundred pounds; the same quantity of rice might be purchased *here* for about £10 sterling. Estimated in money, therefore, wages in England, at £30 a year, are ten times as high as in Bengal; estimated in manufactures, they are more than ten times; estimated in rice, they are about three times as high.

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In comparing the rate of profits in two Countries, this difficulty does not exist; both the advances and the returns being always estimated in money, the apparent must be the real difference between the rate of profits in any two Countries.

The great obstacles to the circulation of labour are difference of climate, distance of place, and difference of language. The first is by far the most powerful, and is so great that there is little voluntary emigration of labourers to a very dissimilar climate. Difference of language seems often a greater obstacle than very considerable distance of place. The advance of wages obtained by an English mechanic in France is greater than he can get by going to America; but ten go to America for one who will venture to France. Differences in habits, government, and religion are comparatively weak obstacles, except in those cases where the differences have caused an antipathy, making immigration dangerous. Few Countries differ more in habits and religion than England and Ireland, or in government than Ireland and the United States. Yet we know how great is the emigration from Ireland to both those Countries. In general, however, the physical and moral obstacles to the emigration of single labourers, or even of bodies of labourers, unless supported and directed by a very considerable capital, are such that it seldom takes place unless under peculiar circumstances; such as those of Ireland and England, or Ireland and America, where the temptation is very great, the physical obstacle only a passage of a few weeks in the one case, and a few hours in the other, and the language the same.

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But the voluntary migrations of capitalists and labourers united, and the attempts by capitalists to force the involuntary migration of labourers, have been among the principal causes that have advanced and retarded the improvement of mankind. To the first class belong those hostile migrations in which a whole nation, in the hope of obtaining a climate or a soil more favourable to production, has moved in a body to seize the territory of a neighbour. From the invasion of Egypt by the Shepherd Kings to that of Greece by the Turks these movements have kept the inhabitants of the whole of our hemisphere in a constant fluctuation. Many Countries, and among them our own, have been so covered by successive strata of occupants, that no trace of the first settlers can be discovered; in others, the poor remains of the aborigines are discovered, like the Helots of Laconia, the Fellahs of Egypt, or the Bheels of Hindostan, by their misery and degradation. Europe, in its present state, does not fear these invasions. They could not be attempted by a civilized nation, nor, in the present state of the art of war, could they be successful *against* one. But, until the improvement of military science and the extensive use of machinery in war, gave to wealth and knowledge their present superiority, these attributes seem to have been sources rather of weakness than of strength. The least polished people seem, on the whole, to have had the advantage. Cicero confesses the warlike superiority of the Gauls over the Romans. It was not till after Gaul had become comparatively civilized that her military fame was recalled as a tradition.* A few centuries of peace made the Britons an easy prey to the Saxons, and the Saxons to the Danes. Under such circumstances the permanent improvement of the human race seemed almost hopeless. And if gunpowder had not been brought into use just at the time when those military virtues which belong to semi-barbarism were decaying, it appears probable that another irruption of barbarians might have brought back another middle age, in which Europe might have lost all that she gained between the XIIth and the XVth Centuries.

Resembling in kind these migratory invasions, but very different from them in effect, have been those emigrations on a smaller scale, to which we give the name of colonization; in which a portion of a comparatively civilized nation have gone out, with their knowledge and wealth, their material, and moral, and intellectual capital, and settled in an unoccupied or thinly peopled district. It is a remarkable and a most unhappy circumstance that, notwithstanding the progress of political knowledge, the true principles of colonization have been less and less understood, or, if understood, less and less acted on, as civilization has advanced. The earliest colonies with which we are acquainted, those founded by the Phœnicians and the Greeks, seem to have been founded for the benefit of the colonists. They were allowed to appoint their own governors, to direct their own industry, and to manage their own concerns; and they relied on themselves for their defence. They were children, but emancipated children; and their progress was in proportion to their independence. The Phœnician colonies in Africa and Syria, and the Grecian colonies in Italy, Thrace, Sicily, and Asia, seem quickly to have risen to an equality with, or to have surpassed, their Mother Countries; to have obtained, in fact, all the wealth and power which their extent of territory, and the religion and knowledge of the times, made it possible to acquire. The Roman colonies scarcely deserve that name. They were generally formed by grants of the lands, the capital, and the persons of conquered Tribes, almost as civilized as their conquerors, to the armies or to the populace of Rome, as a reward for services in foreign or civil war, or for sedition and riot in the forum. It may be a question whether they accelerated or retarded the improvement of the world.

The colonies of modern Europe have been established partly for the benefit of the colonists, and partly, as it was supposed, for that of the parent state. The latter has, in general, contributed a part of the expense of outfit, and almost all the expense of protection against foreign aggression. She has also, in general, given to her colonies a monopoly, or something approaching to a monopoly, of her market. On the other hand, she has, in general, required her colonies to give to her own productions a much stricter monopoly. She has, in general, required her colonies to receive European productions solely from the Mother Country, and to export only to the Mother Country colonial productions. She has, in general, appointed the principal officers, and interfered in the internal management of her colonies. She has not only prohibited the colonists from purchasing in any other market what could be produced in the Mother Country, but has prohibited them from producing for themselves. She has peopled them with the refuse of her gaols, and governed them by the refuse of her aristocracy. The Court of Spain commanded the vineyards of Mexico to be rooted up; the English Parliament forbade Jamaica to discontinue the slave-trade, prohibited the establishment of iron, woollen, and hat manufactures in our North-American colonies, and even now forbids the West Indians to refine their own sugar. The Mother Country dragged the colonists into all her wars, and, from their comparatively defenceless situation, exposed their trade to more loss, and their persons and property to more danger, than she encountered herself. And when the rising strength of the colony rendered these oppressions intolerable, no Mother Country has yet had the good sense to submit quietly to a separation, which, even if it could have been avoided, might have been desirable; and which, whether expedient or not, was inevitable. England, France, Portugal, and Spain have all wasted, in the vain attempt to retain their colonies, ten times more wealth than was expended in founding them.

But, mismanaged as colonies have been, they have, without doubt, been one of the principal means by which civilization has been diffused.

The separate attempts by independent capitalists to procure the voluntary emigration of labourers have generally been made on a small scale, and have been unprofitable to the undertakers, in consequence of the difficulty of compelling or inducing the labourers to perform their engagements, and work diligently at a rate of wages sufficiently inferior to the current rate of the colony to repay the expense and risk of the capitalist. Sir R. Wilmot Horton's plans for effecting emigration on an extended scale, and as a national undertaking, have not received the attention which the magnitude of the probable advantage, and the unwearied diligence and public spirit of its proposer, deserved. And the scheme for founding in Australia a colony in which the first price of all the land shall be employed in

* *Gallos in bello floruisse audivimus.*

Distribution. Inequalities of wages and profit in different Countries.

transporting labourers, has not yet been submitted to the test of experience.

The attempts by capitalists to force the involuntary migration of labourers have been productive of almost unmixed evil. They produced, and have continued, the abominable traffic in which *man* is the commodity;—a traffic which, partly by its direct effects, and partly by the wars and general insecurity which are its necessary accompaniments, retarded more than any other cause the early civilization of Europe; has kept, and continues to keep, the greater part of Asia, and the whole of Africa, in hopeless barbarism; and has divided the inhabitants of the most fertile portions of the Continent of America, and, until lately, those of almost all her islands, into two classes only, the oppressors and the oppressed.

The transfer of *capital* from one Country to another is subject to less difficulty. When the exchange is at par between any two Countries, capital can be transmitted in the shape of money without any expense. And as the occasional loss which occurs when the exchange is against the Country to which it is to be exported is compensated by the occasional gain when it is in favour of that Country, it may fairly be said that monied capital is transferred from Country to Country without expense. The chief obstacle is the unwillingness of capitalists either to trust their capital out of their own superintendence, or to encounter a change of government, habits, climate, and language, by accompanying it. Difference of language, however, is felt as a slight objection by educated men. Nor is difference of government of great importance to those who propose only a transitory residence. The difference indeed is often considered an advantage. During the late war, London was filled by foreign capitalists, whose principal motive was to escape the tyranny of Napoleon. Differences of habits and climate are more material, especially the latter; but even these do not seem to counterbalance a great increase of profit. There is scarcely a port in the civilized world in which a considerable part of the mercantile class does not consist of the natives of Great Britain. The inequality in the rate of profit throughout the civilized world is, therefore, much less than the inequality of wages. And as the general progress of improvement tends more and more to equalize the advantages possessed by different Countries in government and habits, and even in salubrity of climate, the existing inequalities of profits are likely to diminish.

Political Economy.

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Carpentry.

CARPENTRY is the Art of preparing timber principally for the construction of building.

In the following Essay we shall first treat on the nature and properties of timber; we shall then proceed to the practical application of timber to Carpentry, and to the principles and practice of geometrical operations required in working drawings, in order to effect the construction of buildings in the easiest and most substantial manner.

Various Kinds and Properties of Timber.

Timber is obtained either from the trunks or branches of trees. The trunks of trees approach to the figure of the frustum of a cone not differing materially from that of a cylinder, the difference of the diameters at the ends being generally very small. In order, therefore, to describe the properties of timber we shall suppose that, when it is cut into such trunks, the figure of each trunk is that of the frustum of a cone, of which the diameters of the circular ends even of very long pieces do not differ considerably.

When timber is split by any straight-edged instrument, the surfaces which are separated are very nearly in planes, and would pass through the vertex of the cone were the upper part restored; and as the splitting may be made both in parallel and in transverse planes so as to form bars which shall have the areas of their sections as small as we please, the bars may have their right sections as small as threads; such threads are called *fibres*, and timber which has the property of splitting into such small rectilinear parts is said to be straight grained.

If two square bars of equal lengths and breadths be cut from the same trunk or stem of a tree, the length of one of the bars being in the direction of the fibres, the length of the other perpendicular to the fibres, the transverse strength of the bar, of which the length is in the direction of the fibres, would exceed the transverse strength of the bar, of which the length is perpendicular to the fibres, several times; by some experiments the longitudinal bar is three times as strong as the transverse bar. Moreover, a timber bar, of which the length is in the direction of the fibres, will also resist the force of extension or that of compression with much greater effect than when the length is perpendicular or oblique to the fibres. Hence, since timber must always be employed either to resist transverse, extending, or compressing forces, it is always divided for use in the direction of the fibres into bars of various dimensions; and whenever the right section is spoken of, this section will always be supposed perpendicular to the longitudinal arrises, or because the longitudinal arrises are in the direction of the fibres, the right section will be perpendicular to the fibres; moreover, if a bar be rectangular, the dimensions of the right section will be equal to the lengths of two adjacent sides of the rectangle which is the right section of the bar.

Durability and use of oak.

Of timber materials none is more durable than oak; some others are, however, less expensive and easier to work, and are, therefore, preferred on that account. Oak, therefore, is used only occasionally in small quantities.

The general use of fir in building.

Among the timbers which are more easily wrought, fir is the most useful, on account of its durability and strength, the straightness of its fibres, as also the ease by which it may be formed into various figures or cut in every direction. We shall, therefore, direct our attention principally to this species of timber, but not to that of the growth of our own Country, which is not only weaker, but more subject to decay than foreign timber.

Timber is imported into Britain from the North of Europe and from North America. European fir is distinguished by the names of the places from which it is cut; *viz.* Memel, Dantzic, Riga, Norway, Prussian, and Russian, and comes under the forms of *baulk* and *deal timber*. *Baulk timber* consists of the largest square bars which can be cut from the trunks of trees, being generally from eight to sixteen inches square, and sometimes extending to sixty feet in length or more. American baulk timber is of much larger growth than European, being from two feet to two feet six inches square, and in length from twenty-five to fifty feet, or even more.

Baulk timber.

Deals. Their dimensions.

Deals are rectangular bars from two and a half to three inches in thickness, and are also imported from America as well as from the North of Europe. European deals are from ten to twenty feet in length, and from eight to eleven inches in breadth, and American deals are from ten to twelve feet in length, and from nine to eleven inches in breadth. The colour of timber is either red inclining to yellow, or white, and is therefore called yellow and white fir accordingly, or sometimes red and white fir.

The fir timber which is the most esteemed in this Country is imported from Memel, Riga, and Dantzic. Norway fir also is much used for the smaller timbers of a building, and is extremely durable when exposed to the air or kept under ground. Red and white pine are imported from America.

Use of deals in building.

Deals are either white or yellow according to the timber from which they are cut. The best European deals are from Christiana. White deals are also imported from America. Deals are mostly used in joinery. Yellow deal is considerably harder than white deal, and being saturated with turpentine is better adapted for enduring the weather. White deal, from its being less liable to shrink than yellow, is proper for panelling and the finishing of bed-chambers, but is not capable of enduring the weather. The American yellow pine, from being straight grained and uniform in its texture, is excellent for mouldings, and is often used for panels; the white deal of America is very tough and strong, but none of the American firs are durable, and in close places are subject to the dry rot.

Use of oak.

Of home growth wood, oak is the only kind which is very useful in Carpentry. Oak in logs is imported from Holland, Prussia, and other parts of Germany, as also from Russia. Oak thus imported is called *wainscot*, and having a fine grain, and being generally free from knots, and more easily wrought than our own oak, is employed in floors, doors, windows, and the finishings of principal apartments.

Wainscot.

Deals are divided into thin, rectangular bars of the

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Various kinds of deals.

same length and breadth as the deals from which they are cut by means of the pit-saw. Bars thus cut from two to seven inches in breadth, and from half an inch to two inches in thickness, are called *battens*. Bars from seven inches to any greater breadth, and from half an inch to two inches in thickness, are called *boards*, and all boards above nine inches in breadth are called *planks*. Bars are sometimes so cut that their right section is a quadrilateral or four-sided figure, of which two opposite sides are not only unequal, but the greatest is very small compared to either of the other two; such boards are called *feather-edged boards*, and are of the same breadth and thickness as those which are rectangular. There are other names belonging to deal timber when cut into boards, as half-inch, three-quarter inch, inch, &c. to two-inch deal. *Whole deal boards* are those which are one inch and a quarter thick. *Slit deal* are boards made by dividing a three-inch deal by five cuts of the pit-saw into six boards; thinner boards are called *veneers*.

When deals or other timber bars are divided into boards of the same breadth and length by means of the pit-saw, the surfaces of these boards are very liable to change in various parts, from a plane surface, as was intended, to various curved forms.

Kinds of wood in respect of quality.

Though bars and boards may be selected of a texture apparently uniform, the far greater number contain knots at the points in which the branches begin to issue from the tree, and these knots are attended with a coiling of the fibres round each; the wood of such a bar or board is called *curling* stuff. The term *stuff* is a very common expression with workmen for any material they may have to use as timber, &c. *Clean stuff* is that which is without knots or sapwood. *Free stuff* is that which is clean, and works in the operation of planing without tearing. *Frowy stuff* is a piece of timber or board of a soft texture, and with brittle fibres.

Shrinking of timber.

Timber after having been cut into various rectangular bars, when exposed to the weather will contract in breadth and thickness; but after a certain time, in a uniform temperature, will cease to become less. This contraction arises from the expulsion of the natural sap, and may be promoted by various means; but whether by Nature or Art, a piece of wood or timber having undergone this change is said to be *seasoned*.

The surfaces of all rectangular bars, though they may have remained correct after having been cut or divided, will be very liable to change in seasoning, so as to become concave and convex in various directions, and thin bars will be more liable to this change than those which are thicker.

When any face of a board or piece of timber is a quadrilateral, and when the surface is concave between two opposite corners and convex between the other two, the surface is said to *wind*, or to be *winding*.

Timber liable to warp or wind.

Such a form of surface is also said to *warp*, and the effect is called *warping*. Some woods are more liable to warp than others; thus American white deal is more liable to warp than that from the North of Europe. The warping of timber is occasioned by some of the fibres being in a state of tension, and others in a state of compression; circumstances which arise from the unequal exposure of timber in a growing state to the weather, and from knots and other irregularities.

The effect of seasoning timber.

Timber, in the act of seasoning, is not only subject to bend and warp, but is also liable to rend in various places. Timber which is thus partially split is said to be *shaken*. This disagreeable effect may be often prevented before the timber is used by being careful in the seasoning; and after it has been put to use, by painting the exposed surface immediately with two or more coats of oil paint.

Carpentry.

A piece of timber properly seasoned is not liable to warp, or to change its magnitude in any considerable degree; and besides, its stiffness and hardness will be greatly increased. In this state it is best adapted to every purpose of building. Timber is contracted in breadth or in thickness in passing through the various degrees of change from moist or dry weather, and expanded in passing through the contrary state; but whatever variation takes place in a direction perpendicular to the fibres, the change of length in the direction of the fibres themselves will be almost imperceptible.

Compression of timber.

A piece of timber may be compressed in a direction perpendicular to the fibres; so that after the compressing forces are taken away, it will be greatly reduced in breadth or in thickness, but very much increased in hardness. No compressing forces, however, can be employed to shorten its extension in the direction of the fibres, in any sensible degree, without crushing or crippling the fibres.

Use of glue in joining timber.

Another valuable property which wood possesses, is that two or more pieces may be connected together by an intermediate substance called glue. The two pieces thus connected will acquire a degree of adhesion equal to that of the wood itself in separating the fibres longitudinally from each other; and thus two or more boards may be joined edgeways, so as to form a surface to any extent of breadth which may be required. It must, however, be observed, that whenever two or more pieces of wood are glued together, they must not be exposed to a damp situation; and therefore must always be under cover to protect them from the influence of the atmosphere.* No boarding, however, of this description can be made so that one of its surfaces may fill a permanent inclosure, or surrounding border, or frame, from the shrinking of the timber in its transverse direction; and if a board thus glued together be fastened along its two longitudinal edges, (supposing the surface a rectangle,) it will be liable to split, and the exposed surface will be liable to change from its first position.

A series of boards placed together, so that the edges may join each other, and that a right line, or straight edge, stretched along the whole may coincide with the surface of any board thus joining, is called a *plane of boarding*; or, more generally, *common boarding*.

Use of nails in joining timber.

A most useful property of timber is, that a spike or nail of considerable thickness may be driven into a piece of wood of sufficient substance to a considerable depth, or even through its whole breadth, without splitting it, and without having any other effect than merely compressing the fibres on each side: and the adhesion of the nail or spike thus driven is so strong as to require very great power to extract it.

Timber exposed to the action of the atmosphere is subject to speedy decay by rotting; the period of its duration may, however, be greatly prolonged by painting its exposed surface with two or more coats of oil paint; but, previously to the operation of painting, if the sur-

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* Unless the glue be made in the following manner it will not endure the weather. Mix with the glue white lead and linseed oil in a leaden pot, which is considered the best for the purpose, and in this vessel boil them a sufficient time; and the compound of these materials thus prepared will be found to answer the purposes, applying it in the same manner as before described with common glue.

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face be covered with two or more coats of linseed oil, until the wood become saturated to a considerable depth from the surface, this last process will greatly extend its period of duration.

Boards may be bent upon a curved surface, or upon several bars of wood, of which the edges are arranged in a curved surface by means of nails.

How timber is bent.

Timber bars may also be bent by being brought into a pliable state either by boiling or steaming; and in this state, if sufficiently softened by the operation, they may be bent, so that the linear edges may form plane curves, to a certain degree of curvature; but, however pliable the state to which the timber may be reduced, it is very difficult to bend a bar so that the linear edges may form curves of *double curvature*. After a piece of timber has been thus bent, and become cold and sufficiently dry, if it be taken off the mould, the curvature will be lessened in a small degree; and if the ends of the piece are not confined, it will still continue to unbend, as it endeavours to regain its rectilinear direction.

The solid materials fitted for building are stone, brick, metals, and timber. In comparing two square rectangular bars of equal length and of equal breadth upon each side, the one bar being of stone and the other of timber, (we shall say of yellow deal,) then, whether these bars be employed to resist the force of tension or compression, or a force transversely applied, it will be found that the timber bar is the strongest; hence, yellow fir is preferable to stone when used either as a tie or a straining bar, or to sustain a weight or pressure acting transversely. Timber is lighter than stone, and therefore throws less stress upon its bearing supports.

Timber stronger and cheaper than stone.

Moreover, bars of timber can be procured in lengths vastly greater than that of stone, and therefore in this respect more accommodating to a great extent of bearing; and not only so, but to form bars of stone would be much more expensive than those made of timber. Timber is not only preferable to stone in resisting pressure, but also in resisting percussion. The use of brick in resisting a transverse strain, or the force of extension, is altogether out of the question. As to metals, iron is the strongest of those that are sufficiently cheap for common use. Iron bars are stronger than wooden bars of the same scantlings in any of three modes of applying powers; but yellow fir is stronger and cheaper than iron, weight for weight; on this account, therefore, it is more economical, and consequently more generally employed.

Iron has, however, some properties which timber does not possess; *viz.* that it can be easily bent into curves of every degree of curvature, or even formed into the most acute angles, without the strength being sensibly impaired; but straight-grained timber can be bent only into a small curvature; and in no case can a single piece of such timber be formed into an angle without weakening the piece by cutting it across the fibres; neither can two bars of straight-grained timber be joined so as to form an angle, which will not be much weaker at the joint than in any other section of each of the parts.

Use of iron in building.

Thus it is that iron becomes a useful auxiliary in securing the joints of timber framings either in the form of straps, bolts, spikes, or nails, or by any combination of these. Iron is, therefore, a most essential material in the constructive parts of Carpentry.

Comparative uses of timber and iron.

Though timber is more generally employed in this Country than iron, owing to the cheapness and the great ease by which it is wrought, the adoption of the one or the other of these materials will depend upon the purpose to which it is to be employed. If the object be to form such a construction as shall be proof against fire, as also to be of small dimensions, or of small thickness, or even of the same thickness when great strength is necessary, and when the weight is not an object, iron must in this case be preferable to wood. In the introduction of iron, however, it will be of some advantage to remember the following observations.

Carpentry.

Expansion and contraction of iron by heat and cold.

All metals are subject to variation from the extremes of heat and cold; for they are expanded by heat and contracted by cold proportionally in all their dimensions. Moreover, iron, when exposed to the action of the atmosphere, is soon brought to a ruinous state by decomposition. These rapid effects of destruction may be greatly retarded by painting the exposed surface several times over with oil paint.

To resist impressions by violence or accidental force, wrought iron is both cheaper and better adapted than any other material. Cast iron, however, is better calculated to resist oxidation than wrought iron; and therefore, for many purposes is preferable, particularly in bending stone work together. With respect to timber work wrought iron is preferable to cast iron, used as fastenings, in the form of straps, bolts, nails, &c.

Preliminary observations.

In order to have a complete understanding of the adaptation and applications of different materials to building purposes, particularly that of timber, and of the proper forms into which it may be cut, it will be necessary to describe the figures of buildings as will at the same time be both convenient and cheap, and which, if required, may be susceptible of elegance and decoration.

Most economical forms of building.

It is not only economical that every floor should be level, but a level position is also the most easy for walking upon; and because our position in walking is vertical, the surfaces also of all walls within rooms ought to be vertical, at least to a certain height, in order to occupy the area of the floor to the most advantage; moreover, the laws of gravitation require the surfaces of walls to be vertical. In economical buildings, plane surfaces are easier to execute than any other; hence in this case the figure of every room ought to be that of a right prism, of which one of the ends or bases is the plane of the room, and the other end is the ceiling, and of which the sides are the surfaces of the walls. Hence the plan of every room as regards convenience and economy ought to be a rectilinear figure or polygon, and all the faces of the walls, which are the sides of the prism between the ends, should be rectangles.

When a building consists of two or more rooms, in order to occupy the least space and to use the fewest materials, the walls or partitions between them ought to be equally thick; hence every wall, whether exterior or interior, ought to be comprised between parallel planes.

Among all the figures which may be given of the plan of a room, a rectangle is the most convenient for furniture and accommodation; therefore since every rectilinear figure, of which every two adjacent sides form a right angle, may be wholly divided into rectangles of equal or of various dimensions and proportions, the subordinate rectangles will constitute the plans of the rooms and division walls.

A building upon a rectilinear plan having every two adjacent sides reciprocally perpendicular to each other, forming a right rectangular solid figure, is better adapted

for subdivision than one of any other figure, as not only being the least expensive upon the whole, but as every room is more convenient than one of any other figure. For walls which are oblique to one another require more materials at their junction, and are therefore more expensive; and they are not only weaker than those which are at right angles, but they introduce forms which are inconvenient for furniture.

Therefore to execute a building at the least expense, and at the same time to be the most convenient in respect of accommodation and communication, all the dihedral angles of rooms should be right angles; hence all three trehedral angles ought to consist of three plane angles, all which are right angles. Therefore any two distinct surfaces whatever, must either be in the same plane or in parallel planes, or in planes reciprocally perpendicular to each other. Hence any two distinct lines formed at the meeting of these planes must be right lines, which are either in the same right line or in parallel right lines, or in right lines reciprocally perpendicular to each other; moreover, in any such right line and in any plane, the right line will either be in that plane or parallel or perpendicular to it.

Because the plans of all walls and partitions are comprised between parallel lines, and because planes passing along parallel lines are also parallel as well as the lines, the substance of every wall and partition carried upon these planes is comprised between parallel planes. Moreover, as the surface of a floor for walking upon is more convenient and less expensive in a horizontal than in an inclined position, and since in economical buildings every room is the figure of a right prism, of which the floor is one end and the ceiling the other; therefore as the floor is horizontal the ceiling also must be horizontal; and as it is convenient in every story of a building consisting each of two or more rooms, that all the floors of these rooms should be on the same level, therefore the substance of the division between two adjacent rooms, one immediately above the other, is comprised between parallel planes, the upper plane being the floor of the upper room, and the lower plane the ceiling of the lower room; hence the substance of all exterior walls and divisions of rooms ought to be comprised between parallel planes, whether the surfaces are horizontal or vertical; and generally, as all rectangular apertures receding from vertical planes having each two sides perpendicular to the horizon, and consequently the other two parallel, are not only cheaper to form, but the figure is more congenial to the shape of the room than any other; it is for this reason that rectangular apertures are more generally adopted than any other form whatever. All the meeting lines of vertical surfaces, whether external or internal, being right lines perpendicular to the horizon, are much more easily executed than curves, and consequently are cheaper. All the ceilings and floors of buildings, as regards convenience and economy, must be parallel to the horizon. The substance between the apparent surface of the ceiling of one room and the apparent surface of the floor next above is comprised between two parallel planes, as well as the substance of walls and partitions. Moreover, the floors and ceilings of rooms, the soffits of the apertures of doors and windows in economical buildings are parallel to the horizon.

It is therefore from motives of economy and convenience, that the far greater part of buildings are constructed as here described. Hence whenever buildings or rooms are mentioned, though the plan may be of any figure whatever, it will always be considered as a rectangle unless otherwise defined. This is the reason why timbers are generally divided longitudinally into rectangular bars; for if the right section of any timber bar be required of any other figure, it is most convenient to form such a bar from a rectangular one; but bars which require to be of a different figure in their sections will scarcely occur in any part of such building except in the margins or in the several sides of a roof.

All the parts of a habitation which appear to the eye are called *apparent surfaces.* These apparent surfaces ought to be plane figures.

Every material used as a covering, in order to possess sufficient strength and continuity, must have such thickness as is requisite to preserve the apparent face in its due form. This thickness, in the covering of roofs, is the distance between a plane containing the arris lines of the courses, and the plane of arrangement which contain the under faces of the boarding and the edges of the supporting timbers; in partitions and ceilings the thickness of the covering is the thickness of the lath and plaster together, which is equal to the distance between the apparent face of the plaster, and the plane containing the edges of the supporting bars; and in the boarding of floors, the thickness of the covering is the distance between the surface for walking upon and the plane containing the edges of the supporting bars and the lower face of the boarding.

Surfaces to cover hypethral apertures in order to shut the interior, so as to effect the stoppage of rain and inclement weather, as also the rapid discharge of water generated by rain or snow, and at the same time to be both beautiful and cheap, ought to be constructed in inclined planes.

As no apparent surface can exist without substance, we shall call the material, whatever it may be, by the simple name of *covering*, or by the compound names of *covering substance*, or *covering material*, which will always be supposed of uniform thickness.

Every covering will therefore be comprised between two parallel planes. We shall call the plane of this covering opposite the apparent face, the *concealed face* or *invisible face.*

Of Wall Timbers.

All the operations in economical buildings are constructed for the purposes of supporting the apparent coverings, in whatever position or situation they may occur; the materials should therefore be of such strength as will enable them to resist the accidents to which they may be exposed.

The exterior walls being carried up between vertical surfaces, will be best constructed with solid and weighty materials, such as stone or brick bedded in mortar, as the more weighty the materials are, the more capable will be the walls of resisting the pressure of heavy winds and tempests, and their position, if they are sufficiently thick, will prevent the possibility of their falling either to the one side or to the other, and thus it will be impossible for them to produce any lateral pressure; but on the contrary they will be able, if sufficiently thick, to resist any proposed lateral pressure whether applied upon the one side or upon the other.

Applications of brick and stone.

Partition walls are often built with brick or stone bedded in mortar, particularly when it is required that they should contain chimnies. In such cases, where cheapness and the saving of room is required, partitions may be

Carpentry. constructed of timber work adapted to support a covering on both sides of lath and plaster. Such a construction of timber becomes necessary whenever the floor under the partition is unsupported from below, except under the vertical extremities of the frame.

Use of timber in building. Therefore the principal objects to which timber is applied in buildings, are the framings used in supporting the coverings of partitions, floors, ceilings, and roofs.

Timber is also applied in exterior walls; thus long pieces of timber, (*piles,*) and sometimes planking are used in bad foundations; as also for the greater security timber bars (*sleepers*) are laid transversely at short intervals under the foundation, extending about two feet wider. Other timbers (*lintels*) are laid horizontally over the apertures of doors and windows to support the superincumbent part of the wall. Other timber bars (*bond* or *chain timber*) are built into the walls in order to prevent settlements; and others again (*wall plates*) are inserted in order to give a firm support for the timbers of the roof, and those of the floor or floors when such occur in the building; besides these, pieces of timber (*wood bricks* or *plugs*) are built or driven into walls for supporting the timber bars to which the laths for sustaining the plaster is nailed, and for the conveniency of fixing the finishings required in Joinery. Bond timbers, wall plates, lintels, and wood bricks, should always be laid in walls in a horizontal position with two faces parallel and two faces perpendicular to the horizon, and with one of the vertical faces parallel to the faces of the wall. Bond timbers, in order to be the most durable, should be made of oak, and they ought to be placed in the middle of the thickness of the wall, and not to have either of their two vertical faces in the interior face of the wall, as the shrinking or decay of the timber will greatly weaken the substance of masonry or brickwork, and thus will hasten the destruction of the fabric. Bonds made of cast-iron, with one face flush with the interior face of the wall, and with holes at regular intervals for plugs, would not only be proof against fire, but would add greatly to the strength of the wall. After the stone lintel has been laid over the aperture of a window or door, the remainder of the breadth between it and the inside of the wall may be covered with wooden lintels, in order to save the expense of iron or of a stone arch. The thickness of wooden lintels ought to be as many inches as the bearing distance is in feet.

Lintels, bond timber, and wall plates. Wood bricks.

Timbers inserted in a wall, or in walls for supporting the ends of the horizontal timbers in a roof, or those for supporting the ends of the timbers in a floor, are called *wall plates,* and are employed in order to distribute the pressures of the timbers which they support upon the walls. Without wall plates the masonry or brickwork would be liable to be crushed under the ends of the timbers, which would act partially, and thus dislocate the parts underneath; one of the vertical faces of every wall plate should be flush with the interior surface. The sizes of wall plates will greatly depend upon the thickness of the walls, and the weight of the timbers which they have to sustain. In thick partition walls of stone or brick, the wall plates should be double upon each such wall, and their upper faces as well as their lower faces ought to be level.

The greatest care, however, must be taken not to place any timber inserted in a wall, in whatever office that timber is to serve, nearer to a flue than nine inches; and if it be necessary that timbers should be placed, so that they would fall upon flues, the ends must be cut off, and cast-iron ends must be fixed to the timbers, and these must be supported upon cast-iron wall plates or templates.* Carpentry.

Construction of Floors.

When any room in the basement story of a building is intended for living in, a boarded floor will be found the most comfortable; and as boards cannot lie solid without being fixed to some material or other, and as timber is the most convenient for the fixing of timber, a row of timber supporting bars, laid upon dwarf walls, or upon props of stone or brick piers, is generally employed for the fixing of the boarding; the supporting bars for this covering are called *ground joists.*

In a house which consists of two or more stories, the timber work which is necessary for supporting the covering of the floors for walking upon or the coverings of the floors and ceilings together, is called *naked flooring,* and by some writers *carcase flooring.* To accommodate rooms of various dimensions, naked flooring consists of two different kinds. Naked flooring

One species of naked flooring may be constructed with a row of timber bars, which at once supports the floor for walking upon and the ceiling of the room below. This description of naked flooring, which is the most simple of any, is called a *single joist floor.* Single joist floor

When the building has been *carried up*† nearly to the clear height of the story, the inside of the walls must be levelled, so that when the wall plates come to be laid, and the ends of the joists upon the wall plates, as also the ceiling finished, and the floor below is completed for walking upon, the clear height of the story may be equal to that which it was intended to be; then if another story be intended, after having laid the wall plates, and the joists upon the wall plates, the walls must be again carried up, by previously building upon the wall plates in the interval between the ends of the joists, so as to fill up every cavity to the level of the top of the joists. This operation is called *beam filling.* Beam filling

Another mode of constructing naked flooring is to support the supporting timbers by another stronger row of timber bars laid upon the wall plates. The timber bars of the row thus laid, are so notched upon the wall plates as to prevent the timbers being drawn off the top of the wall plates, and therefore from being drawn out of the walls, by pulling the timbers in a direction of their length, without either tearing the ends of the timbers or the wall plates. These notchings, as well as the operation of framing them, are called *cockings.* Cockings.

The building is generally roofed in before the supporting bars are laid, and when they are laid their ends do not penetrate or enter into the thickness of the walls, as the row of timbers upon which they are laid, but only abut upon the interior face of each opposite wall. The supporting bars and the *bearing timbers* which support them are notched into each other, so that the supporting and bearing bars may be comprised between two horizontal planes, of which the distance is less than the sum of the depths of one of the bearing timbers and one of the supporting bars. Each of these rows of timbers is called *joists;* the lower row of bars, or bearing timbers, is called *binding joists;* and the upper Binding.

* For an explanation of this term, see *postea,* p. 235.

† Walls are said to be *carried up* when they are built to any required height. The terms *bring up* and *brought up* are also used for *building up* and *built up.*

Carpentry. row, or supporting bars of the covering, is called *bridging joists*; moreover, the construction of naked flooring is called a *bridged floor*.

and bridging joists.

In order that the timbers may have equal bearings, and that they may have the utmost advantage in point of strength, and in economy, materials, and workmanship, as also to render them convenient for joining one another, and for fixing the coverings, two faces of every two joists, whether in the upper or lower row, ought to be parallel to either face of two opposite walls or sides of the room, and all the intervals of the binding, as well as those of the bridging joists, should be equal to each other. In substantial works, the supporting bars, whether in a bridge floor or in a single joist floor, ought not to be more than one foot from centre to centre, that, is in every two adjacent joists the distance from in to out ought not to exceed one foot.

It is obvious that in bridged, naked flooring, the transverse strength of the bridging joists by a force acting in the middle of one of its bearing distances, (that is, between two binding joists,) should not be greater than the strength of a bridging joist and the binding joists, supporting it by a transverse force acting in the middle of the area comprised by the four sides of the room. Hence it is evident, that the binding joists ought to be placed at much greater intervals from each other than the bridging joists. Therefore, owing to the great distance between the intervals of the bridging joists, the lath upon which the plaster of the ceiling is laid being very thin, cannot be attached to the under edges of the binding joists, without being too weak for sustaining the plaster. Therefore, to render the laths of sufficient strength, another series of supporting bars for the lath and plaster may be introduced and placed at such intervals as will render the bearing distances sufficiently short to give the degree of strength required. The timbers thus introduced are called *ceiling joists*. The ceiling joists are either nailed upon the binding joists, crossing two or more, or even extending from wall to wall in one length; and to save room they may be notched, so as to make shorter nails answer the purpose of fixing them to the binding joists, which ought not to be notched, as they have to support the two coverings; *viz.* the boarding for walking upon, and the ceiling of the room below; or instead of extending the ceiling joists across the timbers, they are sometimes let into the binding joists so as to be very nearly flush with the lower edges of the binding joists, and thus the thickness of the binding joists and bridging joists may be comprised between two horizontal planes, of which the distance is very little more than the depth of a binding joist. This mode of fixing the ceiling joist is not so strong as extending them over the binding joists, which, however, is much more expensive.

Thus in a bridge floor we have a compound frame, consisting of three rows of timber bars, all called by the general name of joists, of which each row of supporting bars or joists is supported by the binding joists, which constitute the middle row.

These rows in economical buildings have all their vertical surfaces in planes which are either parallel or at right angles to each other, as well as to the interior faces of the walls of the building.

Sometimes, however, the walls are at so great a distance from each other, as to cause the entire distance between two horizontal planes, which will just comprise the thickness of the naked flooring, to be so great, as to render the binding joists too weak. Therefore, in order to furnish shorter bearing distances for the binding joists, one or more rectangular timber bars, of the largest scantling which can be found, are introduced instead of walls for supporting the ends of the binding joists, and are called *girders*. The girder or girders ought to divide the length of the room into two or more equal intervals, and their surfaces ought always to be comprised between the parallel planes which comprise the naked flooring.

Carpentry.

Girders.

The part of a bridged floor comprised between two adjacent girders, or between a girder and the wall, in clear space is called a *bay of joisting*, that in the clear of two girders is called a *case bay*; and that in the clear between a girder and the wall is called a *tail bay*. Moreover, when there are no girders, the bridging and ceiling joists between the binding joists in the clear, or between a binding joist and the wall in the clear, are called a *bay of joisting*. A bay of joisting between two binding joists is called a *case bay*, and that between a binding joist and the wall is called a *tail bay*.

Bay of joisting.

Case and tail bays.

Girders are supported by short pieces of timber placed under their ends, which are inserted in the wall. These short pieces of timber, called *templates*, ought to be of sufficient length, to distribute the pressure of the girders to a considerable extent along the wall or walls, because the entire weight of the floor will press upon the templates.

Templates.

We shall call all the timbers which derive their support immediately from the wall, whether they are placed upon wall plates or upon templates, by the name of *bearing timbers*. All bearing timbers ought to be supported at their extremities upon the two walls, which are in the direction of the length of the room; hence in a single joist-floor the length of the joists should be laid in the breadth of the room, and thus the direction of the boarding will extend in the length: in a bridge floor (sometimes called a *double floor*) which has no girder, the binding are the bearing timbers, therefore the direction of the binding joists ought to extend in the breadth of the room, as also the boards which form the covering or floor for walking upon; moreover, in a bridged floor with girders, the girders are the bearing timbers; hence their direction ought to extend in the breadth of the room, as well as the bridging joists; therefore, the binding joist and boarding will extend in the length.

It is obvious that when the plane of a room is square, the strength of the timbers can never be affected, whether they are placed parallel to one side of the room or to the other; hence in such a case as this, and when there are more than two or more rooms upon a floor, the choice of the direction of the timbers will be influenced by the direction of the timbers in the other floors, or by the direction of the boarding. When the direction of bearing timbers extends over two or more rooms, they will be much stronger if they extend in single lengths over both openings.

Wood will resist either by compression or extension, therefore in a building consisting of two or more stories, the walls will be greatly strengthened by the timbers, and will consequently be more capable to resist the pressure of heavy winds or other accidental forces; hence, with such assistance, the walls will not require to be so thick as independent walls of the same height. As a further contribution towards the strength of the building, the wall plates in very substantial buildings are often fixed to each other at the angles, and the two wall plates, which are thus joined, are again joined by a third bar of timber fixed at each end to each of the other two,

at equal distances from the joining of the two wall plates; the three timbers thus joined, encloses a space in the form of a right-angled triangle, the two sides which are perpendicular to each other being equal. The piece of timber which is opposite the right angle is called a *diagonal tie*, or *angle brace*.

Diagonal tie or angle brace.

Floors are generally interrupted by one or more circumstances: every comfortable room must have a fire-place, and whenever a building consists of more than one story, a stair will be necessary to pass from the one to the other. For the safety of the building, in order to prevent its being liable to burning, no joist nor girder ought to be placed near to a fire-place, nor to enter any wall containing flues opposite to the ends of the timbers. But from whatever circumstance bearing timbers are interrupted, instead of inserting the ends of the timbers they are generally cut off, and the ends thus cut off are framed or fixed to a timber bar, and the ends of the timber bar are fixed to the two adjacent joists, which remain uncut. The timber bar which sustains the ends of the joists is called a *trimmer*, and the two joists which support the trimmer are called *trimming joists*. When the trimmer is opposite to flues it is called a *tail trimmer*, if opposite to a fire-place it is called a *hearth trimmer*, and if to make way for a stair it is called a *stair trimmer*, which forms the margin of the landing. Tail trimmers are generally brought close to the wall; but hearth trimmers, on account of the marble slab which is necessary to protect the fire from the timber work, are fixed at some distance from the surface of the adjacent wall.

Various kinds of trimmers.

As the slab which forms the hearth requires a support, the space under the hearth between the trimmer and the wall must be filled with something in order to support the slab; and, since nothing is stronger than an arch, a brick arch is generally thrown over between these extremities as abutments, which are the hearth trimmer and the wall, at such a distance from the apparent surface of the boarding as is sufficient to receive the slab, generally constructed of stone or marble.

The arch thus thrown also is called a *trimmer* by the bricklayer, but to distinguish it from other trimmers, it is called a *brick trimmer*.

The mould upon which the arch is formed is called the centre of the trimmer. It is obvious that the brick trimmer must be comprised between two parallel planes, of which the higher is below the level of the floor, and the lower above the surface of the ceiling.

Scantlings.

In the construction of naked flooring and roofing the small timbers which are used are called by the general name of scantlings, though, perhaps, not with good reason; as this term has been appropriated to the dimensions of breadth and thickness of a rectangular bar, and in regard to squared stones the term is applied to the three dimensions of length, breadth, and thickness.

In the construction of the timber works of floors and ceilings, the arrises of the timber ought always to have a horizontal position and to be perpendicular to the two opposite walls, and consequently parallel to the other two opposite walls.*

Horizontal framings are used in roofs as well as in floors, to prevent the action of the oblique timbers from thrusting out the walls. They also serve to support the timbers to which the ceiling of the room below is attached; such a construction is called a *ceaing floor*.

Construction of Partitions.

Every construction of partitions where the bearing is solid below the framing, ought to be filled with timber bars, called *quarterings*, of which every timber has each of its four faces perpendicular to the horizon, and of which the interval between every two adjacent timbers is equal. But when the floor under the partition is unsupported, as the partition ought not to lay any stress upon the floor, it ought to be supported only at the extremities of the under edge. Now if the partition be filled with timbers, as has been described, the whole weight of these timbers will press upon the unsupported part of the floor. To prevent the strain which they would give, and to make the partition capable of supporting the floor above, and even the floor below, if necessary, two oblique timbers must be fixed in such a manner that the lower end of one must rest upon the one supported extremity, and the lower end of the other upon the other supported extremity. The upper extremities may either meet each other, or meet an intermediate post, or they may meet two intermediate posts with an interval between, in such a manner that each oblique timber may meet the nearest post; between the two posts, opposite to the places where the oblique timbers join, another piece of timber bar must be inserted in the interval. Whether there are two posts with an interval, or only one post, two timbers will meet every post; and, including the post, three timber bars will therefore meet each other. To prevent this timber from moving, the three timbers must be secured to each other at every junction of three timbers: the triple junction of the timbers is called a *joggle*, the oblique timbers are called *braces*, and the intermediate piece is called an *intertie*. Hence, when only one post is used there are three joggles, and when two posts are used there are four joggles; in each case the joggles at the lower ends of the braces are included. The posts, when the partition contains a door, are those which form the sides or jambs of the door, and the intertie is the head of the door. When there is no doorway, the timber along the floor becomes a tie. The whole of the partition is included within a rectangular frame; the post or posts must meet the horizontal sides of the frame.

The interruption of doors in partitions frequently occasions an irregularity in the position of the braces, and, in many cases, so much so as to render their effect insufficient. But since the door is generally much lower than the height of the story, the head of the doorway is extended so as to meet the upright timbers at each extremity of the partition, and thus the rectangular frame will be divided into three rectangular compartments when the partition contains one door, and into four rectangular compartments when the partition

* Bridge floors have been long in use, and had always been considered as the best in order to support the covering and ceiling over a large area, until Professor Robinson caused two models of naked flooring to be made, one being a single-joist floor, and the other a bridged floor, each containing the same quantity of timber, and covering equal areas. These models were each loaded uniformly with small shot until they were broken; the strongest was that constructed of single joist. The same experiment has been recently tried, and the result of Professor Robinson has been verified by Professor Barlow, of the Royal Military Academy at Woolwich. It has, however, been argued in favour of the compound framing, though not in such a manner as to decide the fact, that its use is better calculated to preserve the ceiling from cracking than a single-joist floor with deep joists.

Carpentry. contains two doors; hence the upper compartment, which extends the whole length of the partition, may be framed in the very same manner as the whole would have been when it contained no door, or when it contained one door in the middle; and this framing might even be made of sufficient strength to support the floor above, and the timbers below adjacent to the door or doorways without bracing any of the lower compartments: very frequently, however, the lower compartments are braced as well as that above the door or doorways.

As the timbers which support the lath and plastering are most advantageously arranged when their faces are in planes perpendicular to the horizon, and when their intervals are equal, and as these vertical timbers must rest upon the braces, which would therefore be bent by the pressure, and consequently would either have their effect diminished or entirely destroyed; in order to render them as effectual as they were intended, parabolic arches, described so as to answer to the obliquity of the braces and intertie, are recommended; these arches ought to be double, and opposite to each other, and if they are made of iron, they may either be used as a tie or in a state of being compressed.

Use of parabolic arches in partitions.

The upright quartering for the fixings of the lath being fixed to two such arches will effectually prevent them from descending by their weights, and thus the whole stress will be thrown upon the joggles; the braces and intertie, when there are two posts, will be in a state of compression, but the weight of the timbers upon the arches will lessen the degree of compression upon the straining pieces.

Quarter partitions. Partitions constructed of timber bars to be lathed and plastered are called *quarter partitions.*

There is yet another species of partition constructed with timber posts placed at equal intervals, and filled with brickwork between the adjacent posts, which are called quarters; the quarters are placed at eighteen or twenty-seven inches in the clear, and to strengthen the brickwork, horizontal pieces of timber extend between the quarters over every five or six courses of brick. A partition thus constructed, partly with brick and partly with timber, is called a *brick nogging partition*, and the work done in this manner is called *brick nogging*. The horizontal pieces between the quarters are called *nogging pieces.*

Brick nogging partition.

Brick nogging partitions ought always to be constructed upon a solid foundation, and, consequently, ought never to be used but in ground or basement stories. The quarters ought always to be three-quarters of an inch thicker than the brick, so that half the difference, or three-eighths of an inch, ought to project before each face exhibited by the brickwork, in order to allow for the irregularities of the surface of the lath, occasioned in the splitting by the sinuosities of the fibres in taking curve directions round the knots.

Of the Various Kinds of Roofs.

A *common roof* is that which has only two apparent sides, which meet each other in the ridge, and which rest upon opposite walls, which, in isolated houses, are generally the two opposite walls that have the least interval. This roof is called a *gable ended roof.*

Gable ended roof.

Common hip roof. A *common hip roof* is that which has only one apparent face adjacent to each of the four walls, and the two apparent faces which rise from the two opposite walls, which have the least interval, meet each in the ridge. Carpentry.

As the meeting plane of a hip roof generally bisects the dihedral angle formed by the external faces of two walls which meet each other, every two planes which meet have the same inclination to the horizon, and the right section of a common hip roof between the two most remote walls is a trapezium; but if the dimensions of the aperture to be covered are equal, all the four faces of the roof will meet in a point, and each of the right sections through this point will be an isosceles triangle.

A *truncated roof* is that which is flat upon the top, and may either be of the simple prismatic form or hipped. When it is not hipped it is called a *simple truncated roof*, and when it is hipped it is called a *truncated hipped roof.* A truncated roof is also called a *terrace roof* or *cut roof.* A truncated roof has its right section in the form of a trapezium, with two parallel sides, and the two diagonals equal; the side which is parallel to the base is not absolutely a right line, but is raised in the middle to an obtuse angle for the purpose of discharging the water. The top, which is nearly horizontal, ought to be covered with lead. Truncated roof.

A *curb roof* is that which has two sloping faces upon each side; when it consists only of a simple prism it is called a *common curb roof*, and when it is hipped it is called a *curb hip roof.* A curb roof is also called a *mansarde roof.* Curb roof.

As the roof of a rectangular building may consist of the intersection of two or more prisms, as has been described, these intersections may be either external or internal, that is to say, the dihedral angles of their planes may either advance or retreat, and, accordingly, are called by the French *salient* or *re-entrant* angles; hence when the dihedral angles of the adjacent sides of a roof are *salient*, every two of such which meet each other will form a hip, which has already been described; but when the dihedral angles are *re-entrant*, they form what are called *valleys.* A roof having a valley is called a *valley roof.*

A roof which has both a hip and valley is called a *hip and valley roof.** Hip and valley roof.

The roofs of buildings in which the faces of the walls terminate in horizontal right lines are called *straight roofs*, in order to be distinguished from curved roofs. Curved roofs are generally circular and isolated. We may, however, have both straight and curved roofs independent of each other, or intersecting each other.

Roofs either cover the tops of the exterior walls from which they spring entirely, or only partially; when a straight roof covers the top of the wall, the inclined surfaces are prolonged before the face of the wall several inches, or even feet; such a roof is said to have *dripping eaves*, and the parts thus prolonged are called the *skirts* of the roof; in such a roof the water is supposed to drop from the margins of the eaves upon the ground without being stopped in the way.† Dripping eaves.

* When the plan of a building is curved, the walls are also curved surfaces, and the roof is denominated from the plan of the building, or from the form of the top of the walls; a roof for such a building is called a curved roof. Hence, when the top of the walls from which the roof rises is a circle, the roof is called a *circular roof*, and, if an ellipse, it is called an *elliptic roof*, and so on.

† Such forms of roofs have sometimes troughs placed with a gentle inclination under, but near to the margin of the eaves in order to carry the water into pipes; but the appearance of such appendages is rather unsightly.

Carpentry.

Straight Roofs.

Straight roofs of the most agreeable and best construction ought to have a certain number of dihedral angles. Let us conceive, either in a hip roof, or in a hip and valley roof, a bar to be fixed in the intersection of every such angle; and the plane which bisects the dihedral angle to divide the bar into two equal parts, so that two of its faces may be parallel to the bisecting line.

Let us again conceive, at the margin of every face of the roof which joins the wall another bar to be fixed, so that two sides may be parallel to the horizon; these two faces will therefore make an acute angle with the plane of arrangement, or with the apparent face of the covering; and suppose all these bars to meet each other, so as to form a complete frame surrounding the aperture to be covered; also, let the upper edges of the bars of every such frame be in the plane of the supporting bars of the covering, (that is, their plane of arrangement,) so as to allow for the proper thickness of covering and boarding. If any particular bar is required to project above the apparent face of the covering, draw a right line on the inner face of such a bar which will mark the intersection of the surface of the plane of arrangement.

Ridge piece. The bar in the dihedral angle, of which the line of meeting of its two faces is parallel to the base of the roof, is called the *ridge piece;* and each of the inclined

Hip rafter. bars in the meeting of every two adjacent inclined faces, which form a salient angle, is called a *hip rafter;* and the timber in every face which joins the wall is called

Wall plate. a *wall plate.*

Thus every apparent face of the roof of an economical building will have its enclosure in the form of some of the diagrams, Plate, Nos. 1, 2, 3, 4, &c. to 7. No. 1 is the figure of the apparent sides of a gable ended roof; No. 2 that of a gable end and a hip; No. 3 that of a gable end and a valley; No. 4 that of a hip and valley; No. 5 that of two hips; and No. 6 that of two valleys. The quadrilateral diagrams, Nos. 1, 2, 3, 4, 5, 6, all belong to the longest sides of the roof, and No. 7 to the end of a hip roof.

Here, in this diagram, each timber bar adjacent to each line, or side, is called by the general name of a *bordering piece;* the bordering pieces being joined at the angles will form a triangular or quadrangular form, according as the aperture consists of three or four sides. The frame thus enclosing an open area is called the *surrounding frame.*

In the seven diagrams here referred to, the side B C is supposed to be the skirt next to the wall, and A D that adjacent to the ridge.

Fig. 8 exhibits the plan of a gable ended roof, figures 9 and 10 plans of hip roofs; that of fig. 9 being square, and that of fig. 10 oblong.

Fig. 11 is the plan of a hip and valley roof, or what is called, in reference to the plan, an ell roof, being in form of the letter L; and fig. 12 is the plan of a hip and valley roof in the form of the letter T.* Hip roofs, &c.

All the supporting timbers of every inclined covering of a roof ought each to be perpendicular to the wall plate, and to have two faces perpendicular to the horizon, and a face in the plane of arrangement. All the intervals between every two adjacent rafters ought to be equal to one another; and the breadth of every interval between the frame and the adjacent supporting bar ought not to exceed the breadth of the interval which is common to the supporting bars. Moreover, every supporting bar ought to be fixed at each extremity to opposite parts of the skirting frame.

Hence, if the frame of the apparent face to be covered belong to a hip roof, or to a hip and valley roof, those rafters only can be of equal lengths, which meet a ridge in the summit of the roof and the plate at the bottom; therefore, in the triangular parts, the supporting bars must be shorter and shorter. The supporting bars are generally called *rafters;* and those which are of unequal lengths, and all shorter than the rafters which extend between the plate and the ridge piece, are called *jack rafters.* Rafters. Jack rafters.

But, it is clear, that the longer the rafters are, the greater ought the scantlings to be; therefore their depth, or their thickness, or both their cross dimensions ought to be increased as their length is greater: for if all the rafters were of the same scantling, their strength would be very nearly in a reciprocal ratio of their length. Now, instead of increasing the rafters in thickness, or in depth, or in both these dimensions of breadth and thickness, it is a general practice with builders to make the rafters nearly of the same scantlings for all buildings; and therefore, when they are so long as not to be able to support themselves and the covering without sagging or breaking, it becomes necessary to support every rafter at one or more intermediate points, and thus to divide its length into two or more equal parts.

For the purpose of giving the rafters a sufficient support, it is not only convenient, but economical, to place one or more horizontal rectangular bars, called *purlins,* so that each extremity of every purlin may be fixed to the opposite parts of the bordering frame; and that one of the faces of every purlin, and the lower edges of all the rafters comprised in the length of the purlin, may be all in one plane; and, lastly, that all the intervals between the plate and the ridge may be equal, the number of intervals being one more than the number of purlins. Purlins.

When the roof only covers the top of the walls in part, the front of the walls may be carried up to any required height above the level of the roof, and a construction of wood, in the form of a trough, is covered with thin sheets of metal, generally lead, for the purpose of carrying off the water into pipes, which may either be concealed or exposed, as the circumstance of the building may require. In such constructions the water-ways are entirely concealed, and sometimes the roof itself, by the walls; the wall thus carried up is reduced in its thickness in order to make room for these water-ways, which are called *gutters,* and such roofs are sometimes also called *gutter roofs;* the part of the wall thus carried up is called a *parapet.*

Gutters are not only placed along the horizontal margins of roofs, but are also made in the valleys of return roofs. When the bottom and side of the boarding of the gutters are supported by short pieces of timber, the gutters are called *bridged gutters.*

Gutters should be made sufficiently wide for a person to walk along them with ease when repairs are needed, and they ought to have a sufficient descent that water may run freely along them; but, instead of making one continued descent, it would be more convenient and less expensive to make two wherever circumstances will admit; and the nearer these descents can be made of the same length the less height will be required for the fall of water; because, when long gutters are made in one descent, as the rise upon the whole must be proportional to the length of run, the distance which they cover the roof must be proportional; or, otherwise, if the breadth of the gutter be confined within parallel limits, the depth must be very great to allow for the proper fall of the water.

* It is evident that, in hip roofs, the plane which bisects every dihedral angle will be perpendicular to the horizon: therefore, two faces of every hip rafter, two faces of every valley rafter, and two faces of every ridge piece, ought to be perpendicular to the horizon.

Therefore every rafter in that length will be supported by one point of the purlin, and at as many equidistant points as there are purlins in the length of that rafter, making the intervals one more than the number of purlins.

Here the same observations may be made on purlins as have been offered on rafters; *viz.* that it is customary with builders to make the purlins for all buildings nearly of the same scantling, whatever may be their length. Hence, there is only one necessary length between one prop and another that will sustain the rafters and the covering to the best advantage; therefore, if they have any longer bearing than that which would be just necessary between their extremities, that bearing ought to be divided into two or more equal bearing distances. This may be done by placing a sufficient number of other oblique bars in the same direction as the rafters, so that all the upper edges of these timbers, and the under edges of the purlins, may be in one plane; and that the two ends of the bar or bars thus introduced, may be supported, and of such length as to contribute to the support of all the purlins.

Principal rafters. Common rafters.

The bars for supporting the purlins are called *principal rafters*, and the rafters supported by the purlins are called, by way of distinction, *common rafters*. Again, let it be supposed that the principal rafters are in their turn supported opposite to every purlin, as well as at the two extremities. For this purpose, let as many beams be extended across the building as the principal rafters are in number, and let these beams be supported upon wall plates; *viz.* one plate upon each of the opposite walls in the same manner as the binding joists of a floor were laid upon the wall plates; moreover, let the lower end of every principal rafter be fixed to the end of the beam. Then, if the roof is of the best construction, and be a common hip roof, its right section will be an isosceles triangle; therefore, if on the other side of the roof principal rafters of the same length are supported at their lower extremities, each upon the opposite end of every beam, and if the two equal sides thus constructed for the opposite faces be made to meet each other in a vertical plane passing through the summit, they will necessarily balance each other. However, if they only lean one upon the other, a very small force will destroy their mutual balance: hence, if they are fixed together in any manner so as to prevent them from sliding upon each other, their balance cannot be easily destroyed by any accidental pressure acting upon either side only.

Thus the supports of the purlins have been reduced to a triangular frame of an isosceles figure, the two opposite principal rafters forming the two equal sides and the beams its base. It is obvious that in this state of the timbers, the principal rafters from their own weight, and from the load which they have to support, are in a state of compression, and therefore the beams are in a state of tension.

Tie beams.

Hence the beams are called *tie beams*, and the whole of the triangular frame, together with the timbers it comprises, in order to support the principal rafters most effectually and sufficiently, is called a *truss*, and the principal rafters among builders are often called *principals*. The lower ends of the common rafters, when the construction of the roof requires principals, are fixed to a bar of timber supported upon the ends of the tie beams.

Pole plate.

This bar is called a *pole plate*. The whole of the timbers, including the purlins and common rafters between every two adjacent trusses, is called a *bay of roofing*. The whole of the timber work for supporting the covering is called a *carcass roof*.

The timbers of two skirting frames for supporting the covering of two opposite inclined faces of a hip roof which meet and form the ridge have been described. The two triangular frames in the ends ought to be filled with common rafters supported by the same number of purlins exactly in the same manner as has been explained in respect to the sides of the roof.

In large roofs the construction requires a principal rafter reaching from the middle of the wall plate to the summit, and this is supported below upon a half tie beam, and the feet of the common rafters upon a pole plate is in the two sides which meet and form the ridge.

Whatever may be the form of a straight roof, the timber work for supporting the covering of every inclined aperture ought to be constructed in the manner which has been described. Here, as in naked flooring, the common rafter may be let into the purlins in the same manner as the bridging joists of a floor are let into the binding joists. Hence the entire substance of the rafters and purlins may be comprised between two parallel planes, of which the distance will be less than the sum of the depths of a rafter and purlin. The purlins and principal rafters may also be comprised between two parallel planes, which will be less distant from each other than the sum of the depths of a purlin and a principal rafter.

In roofing, not only horizontal and vertical framings are employed in the construction, but oblique framings also. The oblique framings are those which immediately support the covering.

The vertical framings not only support the oblique framings but the horizontal framings also. The whole of the framings, taken collectively, is called the framing of the roof, and all of them are connected and fixed at the joinings. The timbers belonging to the horizontal frame are disposed similarly to those in the framing of a floor, and the timbers in the vertical frames to those of a partition.

Truncate roofs, &c.

Every truncated or terrace roof ought to have at least two sloping sides, and when such a roof is hipped it ought to have at least three equally inclined faces of which two and two are adjacent, and every adjacent pair of inclined faces form a dihedral angle. Such roofs may also have one or more valleys according to the figure of the plan. The hips and valleys of such a roof, as well as the apertures of the skirting frame, ought to be constructed in the same manner as those of a common roof, or of a common hip roof, or of a hip and valley roof. The upper extremities of the rafters in each face of the roof rest upon a horizontal bar between the inclined face and the flat on the top of the roof; and the principal rafters instead of meeting, have a beam fixed between the top of every two opposite rafters so as to balance them; and thus every truss will consist of four rectangular bars, *viz.* the tie beam, the two principal rafters, and the top beam which is parallel to the tie beam. The top beam, from its rising in the middle in order to give the boarding and leaden covering a gentle inclination, is called a *camber beam*.

Camber beam.

The four timbers of every truss ought to be comprised between the two vertical planes which contain the vertical surfaces of the tie beam. It is evident that in every such quadrilateral truss frame, the top beam and the two principal rafters are in a state of compression,

and the tie beam is in a state of tension. The covering of the aperture on the top, supposing it to be rectangular, may be supported by a row of beams perpendicular to each of the horizontal bars, to the sides of which the ends of the common rafters and the ends of these beams may be fastened. The under edges of the level row of timbers ought to be arranged in the same horizontal plane, but the upper edge or back of every timber extending across the horizontal aperture, is generally cut into a very flat or obtuse angle having the summit in the middle, so that all the summits may be in a right line bisecting the aperture. Each sloping side of the camber beams is boarded over, and the boarding is covered with lead.

In the construction of a curb roof, the lower part being the same in form as a truncated roof, and the upper part the same as a common roof, or a common hip roof, the construction of these parts may be the same as that of common and hip roofs. The horizontal bar between the two inclinations will serve to support the tops of the rafters in the lower inclined face, and the feet of the rafters in the upper inclined face. The beams which in terrace roofs are required to support the boarding, do not require to be cambered in the curb roof, as they only serve the purpose of ceiling joists.

Curb rafters.

Curb plates.

The rafters used in the upper part are called *curb rafters*, and the timbers in the angles which divide the two inclinations are called *curb plates*.

On the Trehedral in general.

A trehedral is a solid angle contained under three plane surfaces called faces, every two of which meet each other, and all the three in a point called *the vertex of the trehedral*.*

Def. The angle formed on any face by the two edges is called the angle of that face, and the face is said to be obtuse or acute, according as the angle of that face is obtuse or acute.†

Def. If from any point in any one of the three edges of a trehedral two right lines be drawn perpendicular to that edge one upon each adjacent face, the angle contained by these lines is called the dihedral angle, which is less than a right angle; it is also called the inclination of the planes.

Def. If a trehedral, of which the angles of the faces are acute, be cut by a plane perpendicular to one of its edges, the triangular section is called a sectional triangle, and each of the three triangles formed by two edges of the trehedral and a side of the sectional triangle is called a lateral triangle.

Def. The edge to which the cutting plane is perpendicular is called the adjacent edge, and the remaining two edges of the opposite face are called opposite edges.*

On the Right Trehedral.

Def. If two of the faces of a trehedral be perpendicular to one another, the trehedral is called a right-angled trehedral.

Def. The two faces of a right angled trehedral which are perpendicular to one another are called the right faces.

Def. The face of a right angled trehedral which joins each of the two right faces is called the oblique face.

Def. If a right trehedral be cut by a plane perpendicular to one of the edges of the oblique face, this edge is called the adjacent edge, the remaining edge of the oblique face is called the opposite edge, and the edge between the two right faces is called the right edge.

Def. If the two right faces of a right angled trehedral be both acute, the trehedral is called a right trehedral.

Def. The right face which terminates in the adjacent edge is called the adjacent face, and the right face which terminates in the opposite edge is called the opposite face.†

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* Generally speaking, timber is divided into solids, of which each is contained by six rectilinear plane faces. The solids thus formed for the construction of buildings have various names according to their relative magnitudes or their destination.

The faces of such solids terminate in twelve edges called by workmen *arrises*, which are right lines, because the intersection of every two planes is a right line. The twelve edges again terminate in eight points, and three of the edges meet each other in each of the eight points. Any three of the right lines which thus meet contain between every two of them a face of the solid. But as the faces are at right angles to one another, the edges are also at right angles to one another. None of the eight trehedrals having the three planes perpendicular to one another, can ever be an object of research, all the parts being known.

But as timber may be cut by planes (that is by saws) in all positions, we may have trehedrals of various forms in which the angles containing the faces may be of all magnitudes.

As we shall frequently make use of the words oblique angle, it will be proper to explain its meaning. An oblique angle is an angle in which one of the sides containing it is not perpendicular to the other, and may therefore be either an acute angle or an obtuse angle. An oblique plane has always a reference to another plane, and implies that the two planes are not perpendicular to each other.

The cutting of timber contained under plane surfaces depends ntirely upon a knowledge of the trehedral, and there is no object constructed in parts with plane joints which does not embrace some case or other of trehedral solutions. We shall therefore proceed to give the remaining definitions, and then to the solution of the different cases.

† PROPOSITION.—*Theorem* 1.

If each of the three faces of a trehedral be acute, its section made by a plane perpendicular to one of the edges, if sufficiently extended, will be a triangle of which a side will be contained in each of the three faces.

For let C V, B V, and A V (plate i. fig. 1) be the three edges of the trehedral, and let the angles of the three faces C V B, C V A, and B V A be each an acute angle, and let the plane F G be drawn perpendicular to one of the edges V C, and let the planes of two of the faces which meet in this edge be prolonged to meet the plane F G, thus let the face C V B meet the plane F G in the line C E and let the face C V A meet F G in the line C D.

Then because the intersection of two planes is a right line, the lines C E and C D are right lines, and because a right line perpendicular to a plane is also perpendicular to every right line drawn in the plane from the point in which the line intersects the plane, the right line C V is perpendicular to the two right lines C E, C D. Moreover, because the angles C V B and V C E are both in the same plane, and because the angle C V B is an acute angle and the angle V C E is a right angle, the two right lines V B and C E will meet; but C E is in the plane F G, therefore V B will meet the plane F G. In the same manner it may be shown that V A will meet the plane F G. Let the edge V B meet the plane F G in E, and the other V A meet it in D, therefore since the intersection of every two planes is a right line, D C E is a rectilinear triangle.

* The definitions hitherto given are general for all kinds of trehedrals; but as two adjacent planes of timbers are generally perpendicular to one another, the oblique trehedral seldom occurs in practice, and whenever it does so the object of inquiry may be obtained by dividing such a trehedral into two others, of which each may have two planes perpendicular to one another. It is therefore to this more limited species of trehedrals to which we shall direct the attention of the reader.

† PROPOSITION.—*Theorem* 2.

In a right trehedral, the three triangles formed by the edges of the trehedral and the sectorial triangle, as also the sectorial triang itself, will be all right angled triangles.

For in fig. 2 let the trehedral be V A C B, in which the point V is

Def. In the sectorial triangle A B C, the angle A is called the vertical angle, the leg adjacent to the vertical angle is called the adjacent leg, and the leg opposite to the vertical angle is called the opposite leg.

Def. The common leg of the sectorial triangle, and the triangle upon any face of the trehedral formed by two edges and that leg, is called the sectorial leg of the triangle in that face.*

Def. The angle contained by the oblique face and one of the right faces is called the inclination of these faces.

Def. The point in which any two of the sides of the sectorial triangle meet each other in one of the edges of the trehedral is called the sectorial point.†

Def. In a right trehedral the two inclinations and the three faces are called parts.

The right angle being always given is not one of the parts. Hence in every right trehedral the number of parts are five. In every right trehedral, when two of its parts are given, a third may be found at one operation.

(1.) In all the diagrams the oblique face is denoted by A V B, the adjacent face by A V C and the opposite face by B V C.

The sectorial triangle is denoted by A B C, and the three sectorial points by A, B, C.

As one inclination is only concerned in our operations, this inclination is denoted by B′ A C or by B A′ C: *viz.*, by B′ A C when the sectorial triangle is placed upon the sectorial line A C of the adjacent face, or by B A′ C when the sectorial triangle is placed upon the sectorial line B C of the opposite face. It being convenient to place the sectorial triangle sometimes upon the one, and sometimes upon the other of these lines.

All the triangles may be entirely detached in the construction, but it is convenient to adjoin in the same manner as they are in the solid. This not only saves lines, but renders the diagram more evident in order to bring the corresponding edges in contact, and thereby form the trehedral.

Keeping the above notation in view, the sectorial lines A B and A C will be each perpendicular to A V, and C B perpendicular to C V.*

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the vertex, and A C B the sectorial triangle, and VA be the edge to which the plane of the sectorial triangle A B C is perpendicular, and let the two right faces be A V C and B V C, and the oblique face be A V B.

The right line V A being perpendicular to the plane of the sectorial triangle A B C will be perpendicular to every right line drawn in the plane from the point A, in which the perpendicular meets the plane; hence V A is perpendicular to each of the right lines A C and A B; therefore, the two triangles V A B and V A C are each right angled at the point A, and are consequently right angled triangles.

Moreover, because the right line A V is perpendicular to the plane B A C, every plane passing along A V is perpendicular to the plane B A C, therefore the plane V C A is perpendicular to the plane A C B; and reciprocally the plane A C B is perpendicular to the plane V C A. But because V C A and V C B are the right faces, the plane V C B is perpendicular to the plane V C A; hence each of the planes A C B and V C B is perpendicular to the plane A C V; therefore their common section B C is perpendicular to the plane A C V: again, a right line which is perpendicular to a plane is perpendicular to every right line drawn in that plane from the point in which the perpendicular meets the plane; hence B C is perpendicular to each of the right lines C V, C A; therefore the triangle V C B is right angled at C, and the triangle A C B is also right angled at C; hence all the four triangles A V B, A V C, B V C, and A B C, are right angled triangles.

Cor. 1. Because the triangle V A B is a right angled triangle, and the right angle is at the sectorial point A, the angles A V B and A B V are each an acute angle; therefore the angle A V B of the oblique face is always less than a right angle, when the angles of the right faces are each less than a right angle.

Cor. 2. Because the sectorial triangle A B C is a right angled triangle of which the vertex of the right angles is in the right edge at C, each of the two angles contained by the oblique plane and each of the right faces is an acute angle.

SCHOLIUM.

From these two corollaries it appears that the sum of the angles of the three faces is less than three right angles, and the sum of the angles contained by every two faces is also less than three right angles.

* *Cor.* The vertical angle A of the sectorial triangle is the dihedral angle formed by the planes of the oblique and adjacent faces, and the hypotenuse A B, the adjacent leg A C, and the opposite leg B C of this triangle are respectively the sides of the lateral triangles opposite the angle of the oblique face, the angle of the adjacent face, and the angle of the opposite face.

Hence if these triangles be all developed upon one plane, the lines which are common in the solid are equal in the developement; that is, the vertical angle A of the sectorial triangle is equal to the angle contained by a right face and the oblique face; the hypotenuse of the sectorial triangle is equal to the sectorial leg in the oblique face; the adjacent leg of the sectorial triangle is equal to the sectorial leg in the adjacent face; and the opposite leg of the sectorial triangle is equal to the sectorial leg in the opposite face.

† PROPOSITION.—*Theorem* 3.

Every right angled trehedral having one or both its right faces obtuse, may be reduced to a right trehedral, or to one which shall have both its right faces acute.

For let in fig. 3 one of the right faces of each of the four adjoining trehedrals, A V B C, A V C D, A V D E, and A V E B, be upon the same base B C D E, so that the oblique faces may coincide two and two in the plane B A D, and the right faces may also coincide two and two in the plane C A E, and let the right faces in the plane B C D E be called the bases, and the other right faces the vertical faces.

The bases of these trehedrals being right lines cutting one another, are either adjacent or opposite, that is, in opposite angles.

Now let each of the three trehedrals A V C D, A V D E, and A V E B, be compared with the trehedral A V B C, in which both the right faces A V C and B V C are acute. Then, because the angle B V C is acute, and the two angles B V C and C V D are together equal to two right angles, the angle C V D is obtuse; and because C V D and D V E are equal to two right angles, and the angle C V D is obtuse, the angle D V E is acute; and because D V E and E V B are equal to two right angles, and the angle D V E is acute, the angle E V B is obtuse.

Moreover, because the angles A V C and A V E are together equal to two right angles, and the angle A V C is acute, therefore the angle A V E is obtuse; hence the trehedral V A C D has an obtuse base, C V D, and an acute vertical face C V A, and is joined to the trehedral V A B C by the common vertical face A V C; the trehedral V A D E has an acute base D V E and an obtuse vertical face A V E, and the two trehedrals A V D E and A V B C are opposite each other, and have their vertical faces in one plane, and their oblique faces in another plane; and lastly, the trehedral V A B E has an obtuse base B V E and an obtuse vertical face A V E, and the two trehedrals V A B E and V A B C are joined to each other by the common oblique face A V B, and hence the proposition proposed to be proved is true.

COROLLARIES.

Hence, 1. If a right angled trehedral, of which the base is obtuse, and the vertical face be given, find the adjacent trehedral, so that the vertical face may be common to the trehedrals.

2. If a right angled trehedral, of which the base is acute, and the vertical face obtuse, be given, find the trehedral upon the opposite base.

3. If a right angled trehedral, of which both its base and vertical face are given, find the adjacent trehedral so that the two trehedrals may have a common oblique face.

In any of the three cases the trehedral to be found will have all its parts, and the like parts of both will be either equal or supplementary to each other. The common faces and opposite bases will always be equal, as well as the dihedral angles which terminate in the same right line, and upon the same side of this right line, and the adjacent faces will be supplements of each other, as well as the dihedral angles adjacent.

* Notwithstanding the variety of cases, which are sixteen in number, every construction is extremely easy, as there is no case

PROPOSITION.—*Problem* 1.

(2.) Any two of the three parts, the inclination, the adjacent face, and the oblique face of a right trehedral, being given to find the third part.

Preliminary.

The adjacent and oblique faces A V C, A V B being constructed, the triangles upon these faces will have a common leg V A upon the adjacent edge, therefore the sectorial line upon each face will be perpendicular to V A; hence the construction may be found from one of the three following rules.

RULE I.

(3.) When the inclination is required, the adjacent and oblique faces must necessarily be given.

1. From any convenient point, A, in the adjacent edge V A, draw the sectorial line upon each of the two given faces.

2. The sectorial line upon the adjacent face, and the sectorial line upon the oblique face being drawn, the adjacent leg and hypotenuse of the sectorial triangle will be given to find the vertical angle.

3. The vertical angle being found will be the inclination required.*

RULE II.

(4.) When the oblique face is required, the adjacent face and the inclination must necessarily be given.

1. Upon the adjacent face draw the sectorial line.

2. Having drawn the sectorial line upon the given adjacent face, the adjacent leg and the vertical angle of the sectorial triangle are given to find the hypotenuse.

3. Having found the hypotenuse of the sectorial triangle, the lateral and sectorial legs of the triangle upon the oblique face will be given to find the angle at the vertex, or opposite the sectorial side.

4. The angle at the vertex being found, will be the angle of the oblique face required.†

RULE III.

(5.) When the adjacent face is required, the oblique face and the inclination must necessarily be given.

1. Upon the given oblique face draw the sectorial line.

2. Having drawn the sectorial line upon the given oblique face, the hypotenuse and an angle of the sectorial triangle are now given to find the adjacent leg.

3. Having found the adjacent leg of the sectorial triangle, the lateral leg and sectorial leg of the triangle upon the adjacent face are now given to find the vertical angle.

4. The vertical angle of the lateral triangle being found is the angle of the adjacent face required.*

PROPOSITION.—*Problem* 2.

(9.) Any two of the three parts, the inclination, the oblique and opposite faces of a right trehedral being given, to find the remaining third part.

The oblique and opposite faces A V B, B V C, fig. 6, 7, and 8, being concerned, the lateral side of the two adjoining triangles will be their common hypotenuse B V; and the sectorial lines will therefore be perpendicular one to each of the unconnected edges A V and C V. Hence, by the following Rules, the part required may be found.

RULE I.

(10.) When the inclination is required, the oblique and opposite faces will necessarily be given.

1. Draw the sectorial leg upon each of the two given faces.

2. The sectorial leg upon the oblique face, and the sectorial leg upon the opposite face being drawn, the hypotenuse and the opposite leg of the sectorial triangle will be given to find the vertical angle.

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that requires more than three right angled triangles in the diagram, and when the same triangle occurs, it is uniformly denoted by the same letters. Though the number be sixteen, seven or eight of these are sufficient for our present purpose.

* *Example* 1. *to* RULE I. PROPOSITION.

(6.) Given the oblique face A V B, fig. 4 or 5, and the adjacent face A V C of a right trehedral, to find the inclination.

1. Take any convenient point A in the adjacent edge V A, and draw the right lines A B. A C, each perpendicular to A V.

2. Draw C B′ perpendicular to A C, and from the point A with the distance A B cut the perpendicular C B′ in B′. Join A B, and the angle C A B′ is the inclination required.

† *Example* 2.

(7.) Given the adjacent face A V C, and the inclination of a right trehedral, to find the oblique face A V B.

1. Having as before assumed the point A in V A, draw the right line A C perpendicular to A V.

2. At the point A with the right line A C make the angle C A B′ equal to the given inclination, and draw the right line C B′ perpendicular to A C.

3. Draw the right line A B perpendicular to A V; make A B equal to A B′, join B V, and A V B is the angle of the oblique face required.

* *Example* 3.

(8.) Given the oblique face A V B, the inclination B A C of a right trehedral, to find the adjacent face A V C.

1. Draw the right line A B perpendicular to A V.

2. Draw A C perpendicular to A V; make the angle C A B′ equal to the given inclination, make A B′ equal to A B, and draw B′C perpendicular to A C.

3. Join V C, and A V C will be the angle of the adjacent face required.

In order to find any of the three parts required by computation, we shall here give the investigation of the three formulæ, and as this can be done according to any of the three Rules, we shall adapt this process to Rule I., in which the dihedral angle is required to be found as being the most simple.

Let VA = radius = 1; then will A B = tan AV B, and A C = tan AV C.

Now in the right angled triangle A B′ C are given the adjacent leg A C and the hypotenuse A B to find the vertical angle C A B′. By trigonometry making radius upon A B′ and the cosine therefore upon A C, the following analogy will give an equation from which any of the three parts may be found.

$$A B' : A C :: \text{radius} : \cos C A B' = \frac{A C \times \text{rad}}{A B'} = \frac{\tan A V C}{\tan A B V'}$$

hence

$$\tan A V C = \tan A V B \times \cos C A B',$$

$$\tan A V B = \frac{\tan A V C}{\cos C A B} = \tan A V C \times \sec C A B$$

because $\sec = \frac{1}{\cos}$,

$$\cos C A B = \frac{\tan A V C}{\tan A V B} = \tan A V C \times \cot A V B;$$

because $\cot = \frac{1}{\tan}$.

These equations in terms of the trehedral will be thus expressed:

tan adjacent face = tan opposite face × cos inclination.

tan oblique face = tan adjacent face × cos inclination.

cos inclination = tan adjacent face × cot oblique face

3. The vertical angle being found, will be equal to the inclination.*

Rule II.

(11.) When the opposite face is required, the oblique face and the inclination must necessarily be given.

1. Draw the sectorial leg upon the given oblique face.

2. The sectorial leg upon the oblique face being found, the hypotenuse and the vertical angle of the sectorial triangle will now be given to find the opposite leg.

3. The opposite leg of the sectorial triangle being found, the hypotenuse and the sectorial leg of the triangle upon the opposite face will be given, to find the angle of this opposite face.

4. The angle of the opposite face being found is the angle required.†

Rule III.

(12.) When the oblique face is required, the opposite face and inclination must necessarily be given.

1. Draw the sectorial line upon the given opposite face.

2. The sectorial line upon the opposite being found, the vertical angle and opposite leg of the sectorial triangle will be given, to find the hypotenuse.

3. The hypotenuse of the sectorial triangle being found, the hypotenuse and sectorial leg of the triangle upon the oblique face will be given, to find the angle opposite to the sectorial leg.

4. The angle opposite the sectorial leg being found, will be the angle of the oblique face required.‡

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* *Example to* Rule I. Proposition II.

(13.) Given the oblique face B V A, (fig. 6 or 7,) and the opposite face B V C of a right trehedral to find the inclination.

1. Draw the right line B C perpendicular to C V, and the right line B A perpendicular to A V.

2. From the point B, with the distance B A, cut V C, or V C prolonged in A′, and join A′ B. Then B A′ C is equal to the inclination required.

This case is applicable to the ranging of hip rafters, and to finding the dihedral angles of the regular solids.

† *Example to* Rule II.

(14.) Given the inclination B A C, (fig. 8,) and the oblique face A V B of a right trehedral, to find the opposite face B C V.

1. Draw B A perpendicular to A V.

2. At the point A, with the right line A B, make the angle B A C′ equal to the given inclination, and draw B C′ perpendicular to A C′.

3. Upon V B as a diameter describe the semicircle B C V; from the point B, with the distance BC′, cut the semicircular arc in C, and join C V. Then B V C is the angle of the opposite face required.

‡ *Example to* Rule III.

(15.) Given the inclination B A′ C, (fig. 8.) and the opposite face B V C of a right trehedral, to find the oblique face.

1. Draw B C perpendicular to V C.

2. In V C, or in V C prolonged, take any point, *c*, and draw *c d*, making the angle C *c d* equal to the given inclination; and from B draw the right line B A′ parallel to *d c*, meeting C V in A′.

3. Upon V B as a diameter describe the semicircle B A V; and from the point B, with the distance B A′, cut the semicircle in A. Join A V and A B. Then the angle B V A is equal to the angle of the oblique face required.

The methods of finding the formula when two parts out of the three parts concerned in the proposition are given to find the third, are similar to those investigated in the note to the example of Rule I. It will, therefore, be only necessary to give the three expressions in terms of the right trehedral.

1. sin opposite face = sin oblique face × sin inclination.
2. sin oblique face = sin opposite face × cosec inclination.
3. sin inclination = sin opposite face × cosec oblique face.

Proposition.—*Problem* 3.

(16.) Any two of the three parts, the inclination, the two right faces of a right trehedral being given, to find the third, or remaining part.

Preliminary.

The two right faces being concerned, the lateral edge of the two adjacent triangles will be the right edge, and will be the leg of the triangle upon the opposite face, and the hypotenuse of the triangle upon the adjacent face. Hence, the part required may be found by one of the three following Rules.

Rule I.

(17.) When the inclination is required, the two right faces must necessarily be given.

1. Draw the sectorial line upon the adjacent face, and the sectorial line upon the opposite face.

2. Having drawn the sectorial lines upon the adjacent and opposite faces, the adjacent and opposite legs of the sectorial triangle will be given to find the vertical angle.

3. The vertical angle being found will be the inclination required.*

Rule II.

(18.) When the opposite face is required, the inclination and adjacent face must necessarily be given.

1. Draw the sectorial line upon the adjacent face.

2. The sectorial leg being drawn upon the adjacent face, the vertical angle and adjacent leg of the sectorial triangle will be given to find the hypotenuse.

3. The hypotenuse of the sectorial triangle being found, the lateral and sectorial legs of the triangle upon the opposite face will be given, to find the angle opposite to the sectorial leg.

4. The angle opposite to the sectorial leg being found, will be the angle of the opposite face required.†

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* *Example to* Rule I. Proposition.

(20.) Given the adjacent face A V C, (fig. 9,) and the opposite face B V C of a right trehedral, to find the inclination.

1. Draw C A perpendicular to A V, and C B perpendicular to C V.

2. Draw C B′ perpendicular to C A, and make C B′ equal to C B. Join A B′; then the vertical angle C A B′ is equal to the inclination required.*

Or thus, instead of 2. (fig. 10 and 11.)

2. Having drawn C A and C B as in 1. From the point C, with the distance C A, cut C V, or C V prolonged in A′, and join A′ B. Then the vertical angle C A′ B is the inclination required.

N.B.—This Problem is applied in Carpentry to the ranging of hip rafters; and in Sciography to the shadows of cylinders in all positions, as also to the shadows of polygonal and circular rings.

† *Example to* Rule II.

(21.) Given the inclination B′ A C, (fig. 9,) and the adjacent face A V C of a right trehedral, to find the opposite face B V C.

1. In the connecting line V C of the two faces concerned, take any point C, and draw C A perpendicular to A V.

2. At the point A, with the right line A C, make the angle C A B′ equal to the given inclination, and draw C B′ perpendicular to C A.

3. Draw C B perpendicular to C V; make C B equal to C B′, and join B V. Then C V B is the angle of the opposite face required.

Or thus, instead of 2. and 3.

2. In C V, (fig. 10 and 11,) or in C V prolonged, cut off the part C A′ equal to C A, and make the angle C A′ B equal to the given inclination. Draw B C perpendicular to C V.

3. Join B V, and C V B is the angle of the opposite face required.

N.B. This Problem is applied in perspective in finding the vanishing line of a plane, and in Dialling to finding the hour lines, the angle which the style makes with the substyle being given.

* Formula for the arithmetical computation.

tan opposite face = tan inclination × sin adjacent face.
tan inclination = tan opposite face × cosec adjacent face.
tan adjacent face = tan opposite face × cot inclination.

RULE III

(19.) When the adjacent face is required, the inclination and opposite face must necessarily be given.

1. Having drawn the sectorial line upon the given opposite face, the vertical angle and opposite leg of the sectorial triangle will be given, to find the adjacent leg.

2. The adjacent leg of the sectorial triangle being found, the hypotenuse and sectorial leg of the triangle in the adjacent face will be given, to find the angle opposite to the sectorial leg.

3. The angle opposite to the sectorial leg being found, will be the angle of the adjacent face required.*

PROPOSITION.—*Problem* 4.

(23.) Any two or three faces of a right trehedral being given to find the third.

General Rule.

When any one of three faces is required, the other two must necessarily be given, and these may either be the two right faces or one right face and the oblique face. If the two right faces be given, the lateral right edge V C must be the connecting edge, but if the oblique face and a right face be given, the right face may always be supposed to be the adjacent face A V C, and consequently A V the adjacent edge.

As the face to be found may be attached to either of the unconnected edges of the two given faces, the lateral side of the triangle to be found, attached to the unconnected edge, must either be a leg or hypotenuse of the triangle in the face required, but as one of the two may always be chosen, the leg will afford the most easy construction; hence,

If the lateral edge, to which the third face of the trehedral is connected, be a leg, draw a right line from the sectorial point perpendicular to the leg, and the sectorial leg will be upon this perpendicular from the sectorial point, and from the vertex of the lateral faces with the length of the other unconnected lateral edge cut the perpendicular, join the point of section and the vertex. Then the angle at the vertex will be the angle of the face required.

But if the lateral edge to which the third face is connected be the hypotenuse of the triangle in the face required, describe a semicircle on this hypotenuse as a diameter, and from the vertex of the trehedral faces with the length of the other unconnected lateral edge cut the semicircular arc. Join the vertex of the faces and the point of section, and the angle by the line and the diameter of the semicircle is the angle of the face required.

Though the construction is easier when the face required is attached to a leg, yet as the intersection of the arc described from the vertex and the sectorial leg is sometimes occasionally very oblique, a preference on this account, when it so happens, may be given to the other construction, when the face required is attached to the hypotenuse.

N. B. When the two right faces are given, either may be made the adjacent face.*

* *Example to* RULE III.

(22.) Given the inclination B A′ C (fig. 10 and 11) and the opposite face B V C of a right trehedral, to find the adjacent face A V C.

1. In V C take any convenient point C, and draw C B perpendicular to C V.

2. In C V, or in C V prolonged, take any convenient point c, and draw $c\,d$, making the angle C $c\,d$ equal to the given inclination. Draw B A′ parallel to $d\,c$, making C V, or C V prolonged in A′.

3. Upon C V as a diameter describe the semicircle C A V; and from the point C with the distance C A′ cut the semicircumference in the point A. Join A C and A V, then C V A is the adjacent face required.

N. B. This Problem is used in Sciography, in order to find the lines of light and shadow in a cone.

* *Example to* PROPOSITION IV.

(24.) Given the two right faces of a right trehedral to find the oblique face.

Let the adjacent face be C V A, (fig. 12,) and therefore the opposite face C V B′.

Now, in the adjacent face, the sectorial leg is perpendicular to the adjacent edge V A, and in the opposite face the sectorial line is perpendicular to the right edge; therefore,

1. Draw C A perpendicular to V A, and C B′ perpendicular to C V.

2. Let it now be required to find the oblique face attached to the adjacent edge V A. Draw A B perpendicular to A V, and from the point V with the distance V B′ cut the right line A B in B, and join V B. Then A V B is the oblique face required.

SCHOLIUM.

The four Propositions now given will be found to apply to every useful purpose in Carpentry, Perspective, Sciography, and Dialling. As to the case in which the two dihedral angles and one of the right faces, and that in which the two dihedral angles and the oblique face are concerned, we shall leave for the exercise of the reader, who will now, if he understands the preceding Propositions, not be at any loss to supply the two Theorems just now mentioned.

The three faces being the parts of the trehedral concerned, any two being given as above, we shall here give the investigation of the formula for finding any one of the three parts from the other two being given.

Let C V = radius = 1, then will V B = sec C V B, and V A = cos C V A. Now since by construction V B = V B, V B′ = sec C V B; hence in the triangle B′ A V the hypotenuse V B = sec C V B, and the leg V A = cos C V A, are given to find the angle B V A; therefore, making radius upon B V, the cosine of the angle B V A will be upon V A; hence

$$\text{V B}' : \text{V A} :: \text{rad} : \cos\ \text{B V A} = \frac{\text{V A} \times \text{rad}}{\text{V B}'} = \frac{\cos \text{C V A}}{\sec \text{C V B}} = \cos \text{C V A} \times \cos \text{C V B}.$$

Hence $\cos \text{C V A} = \cos \text{B V A} \times \sec \text{C V B}$;

and $\cos \text{B V A} = \cos \text{C V A} \times \cos \text{C V B}$; these expressed by the parts of the right trehedral, will be

cos one right face = cos oblique face × sec other right face.

cos oblique face = cos one right face × cos other right face.

But before we dismiss this part of our Treatise, it will be found useful to show how this last Problem may be constructed by another principle independent of the trehedral.

(25.) Let g V d (fig. 13) be one of the right faces, and let g V be the edge of the other right face which is common to the two faces, and let V be the common vertex of these faces.

Through any point g in V g draw $g\,b$ in any convenient position, and prolong d V to any convenient point A. From the point g with the distance g A describe the arc A b, and from the same point A with the distance g V describe the arc V c meeting $g\,b$ in c. Make the angle $g\,c$ F equal to the angle contained by the other given right face, and draw g F perpendicular to $g\,b$.

From the point F with the radii F b, F c describe the arcs b D, and c E, and from any convenient point E in the arc c E with the distance V A cut the arc b D in D. Join F E, E D, and F E D will be the supplement of the angle required.

For suppose the other right face to be placed upon g V with its vertex in V, and to be perpendicular to the plane g V b. Draw g F′ in the vertical face perpendicular to $g\,b$; then the vertical face will meet the oblique face in a right line F′ V which is the hypotenuse of a right angled triangle of which g V is the base, and therefore the angle F′ V d will be the angle of the oblique face. Imagine g A and F′ A to be joined, then F′ A will be the subtense of the angle F′ V A, which will be the supplement of the oblique face. Now because $g\,c$ is equal to g V, and g F is equal to the perpendicular g F of the imaginary vertical face, the right angled triangle $c\,g$ F will be equal to the right angled triangle V g F′ in the vertical face; hence the hypotenuse c F is equal to the hypotenuse c F′ in the vertical face. In like manner,

Carpentry.

Definitions.

Def. A plane to which the relations and positions of points, lines, and planes are given, and on which, from these data, other relations are determined, is called the *primitive plane*.

Def. A point, line, or plane is said to be in space when it is situated out of the primitive plane, and a line or plane is still said to be in space, even though one extremity of the line or plane should come in contact with the primitive plane.

Def. If a right line be drawn from any point in space perpendicular to the primitive plane, the point in which the right line meets the primitive plane is called the *projection of the point*, and the right line itself is termed the *projectant of that point*.

Def. A right line drawn through the projections of two points of another right line in space, is called the *projection of this right line*.

Def. A line or a point is said to be given when its relations to the primitive plane are given.

Def. A right line is given in space when the projection and inclination of the line is given, or when the projections and projectants of two of its points are given, or provided the line meet the primitive plane when the point of coincidence and the projection and projectant of one of its points are given.

Def. A point is said to be given either when it coincides with the primitive plane, or when its projection and projectant are given, or when the distances from the point to three given points upon the primitive plane are given.

Def. A right line is said to be given either when it coincides with the primitive plane, or when its projection and inclination are given, or when it is parallel to the primitive plane, and the projection of the line and the projectant of one of its points are given; or any line obliquely situated is said to be given when the projections and projectants of two of its points are given; or a right line meeting the primitive plane is also said to be given, when the point of contact and the projection and projectant of one of its points are given.

Def. A parallel plane is understood to be that which is parallel to the primitive plane.

Def. An oblique plane is that which has an inclination to the primitive plane.

As the intersection of two planes is a right line, the oblique plane will meet the primitive plane in a right line.

Def. The right line in which an oblique plane meets the primitive plane, is called the *trace of the oblique plane*.

Def. The trace of a plane is said to be given when a right line is drawn upon the primitive plane, so that the edge of the oblique plane, supposed to be a right line, may coincide with the line thus drawn for its trace.

Def. A parallel plane is said to be given when the projectant of any one of its points are given.

Def. An oblique plane is said to be given when its trace and inclination to the primitive plane are given.

Or when its trace and the projection and projectant of one of its points are given.

Or when the projection and projectants of three of its points are given.*

PROPOSITION.—*Problem* 1

(26.) To find the primitive inclination of a plane which shall have a given trace, and which shall contain a given right line meeting the trace.

Here in the right trehedral are given the vertical and primitive faces to find the primitive inclination.

Now as the primitive inclination is the inclination concerned, the primitive face is the adjacent face A V C, and the vertical face the opposite face B V C.

This Proposition, therefore, becomes the following Problem:

The adjacent face A V C and the opposite face B V C of a right trehedral being given to find the inclination..

The solution of this Problem will be found as in (20.) fig. 9.†

PROPOSITION.—*Problem* 2.

(27.) To find the vertical inclination of a plane which shall have a given trace, and shall contain a given right line meeting the trace.

Here in the right trehedral are given the vertical and primitive faces, to find the vertical inclination.

Now as the inclination concerned is the vertical inclination, the vertical face must be the adjacent face A V C, and the primitive face the opposite face B V C.

This Proposition, therefore, becomes the following Problem:

The adjacent face A V C and the opposite face B V C, of a right trehedral being given to find the inclination.‡

if F *b* supposed to be joined, the hypotenuse F *b* will be equal to the hypotenuse F A in the oblique face. But F E is equal to F *c*, and F D equal to F *b*; therefore the three sides of the triangle in the oblique face are equal to the three sides of the triangle F E D; therefore the obtuse angle F E D will be equal to the supplement of the oblique face.

* The angle contained by the trace of a plane, and the projection of a right line contained in the plane, is one of the right faces of a right trehedral, and is situated in the primitive plane; because both the trace of the plane and the projection of the right line are situated in the primitive plane. The angle of projection of the right line is the other right face of the trehedral, and is in consequence in the vertical plane; and the angle which the right line makes with the trace of the plane is the oblique face of the trehedral.

When it is said that an oblique right line is given, it must be understood that the projection and angle of the projection of the right line is given.

When it is said that an oblique right line is required, it must be understood that the projection and angle of projection are required.

When the trace of a plane is required, it must be understood that the projection of the right line must be given, and the angle contained by its projection and the trace of the plane must either be given or found.

When the projection of a right line contained in a plane is required, it must be understood that the trace of the plane must be given, and the angle which the trace makes with the projection of the line found.

Of the two inclinations of a right trehedral, the one, formed by the oblique face and the primitive plane, is called for the sake of brevity the *primitive inclination*; and the other, formed by the oblique and vertical faces, is called the *vertical inclination*.

When only one of the two inclinations is concerned in the proposition, this inclination must be either given or required, but whichever of the two it is, the right face which forms the inclination with the oblique face must be the adjacent face; that is, when the primitive inclination is given or required, the *primitive face* must be the *adjacent face*; and when the vertical inclination is given or required, the vertical face must be the adjacent face.

† This Problem is applied to the shadows of cylinders in all positions, to a given position of the Sun's rays, as also to the shadows of polygonal and circular rings.

‡ This Problem only differs from the last in the vertical inclination being required in this, and the primitive in the last; but both are resolvable into the very same case of the trehedral, (20.) fig. 9, when we abstract the trehedral from any position in regard of the primitive plane.

This is the case which applies to the ranging of hip rafters, when the angle which the hip makes with its projection, and the angle which the projection makes with the wall plate, are given.

Proposition.—*Problem* 3.

(28.) To find the inclination of a plane, so that the plane shall have a given trace, and shall be parallel to a given right line.

Let D E (fig. 14) be the trace of the plane, C′ V′ the projection of the right line, V any convenient point in D E, and C any convenient point in V′ C′.

Make the angle C′ V′ B′ equal to the angle of projection, and draw V C parallel, and make it equal to V′ C′. Draw C A perpendicularly upon D E, C B perpendicular to C A, and C′ B′ perpendicular to C′ V′. Make C B equal to C′ B′, and join A B. Then C A B is equal to the inclination required.

This Problem is equivalent to that of having the two right faces of a right trehedral to find one of the inclinations, which is here the horizontal inclination, the two right faces being C V A and C′ V′ B′. (17.) (20.)

Proposition.—*Problem* 4.

(29.) The trace A V (fig. 12) of a plane, and a right line parallel to the plane being given, to draw a right line in the plane from a given point V, in the trace parallel to the given right line.

Let D E be the projection of the right line, and let V be the given point in the trace A V of the plane.

Draw V C parallel to E D, and at the point V with the right line C V, make the angle C V B′ equal to the angle of projection of the line.

Here we have now given the two right faces C V A, C V B′ of a right trehedral, to find the oblique face, (23.) (24.) and we shall find that A V B is the oblique face required.

Thus the oblique face will be found without previously ascertaining the inclination of the planes.*

Proposition.—*Problem* 5.

(30.) Two oblique right lines being given, to find the trace of a plane which shall contain one of the lines and be parallel to the other.

Let A B (fig. 15) be the projection of one of the lines, and C D that of the other.

Draw B E parallel to C D. Draw B F′ perpendicular to B E, and B F perpendicular to B A. Make the angle B A F equal to the angle of projection of the line, of which the projection is A B, and make B F′ equal to B F. At any convenient point in B E, make the angle B *i h* equal to the angle of projection of the right line, of which the projection is C D, and draw F′ E parallel to *h i*. Join A E, then A E joined is the trace of the plane required.†

* These two last propositions will be applied to cylindrical vaulting upon an inclined plane, where they are indispensable.

† For imagine the right angled triangles A B F and E B F′, to be raised upon their bases A B and B E, until B F and B F′ be each perpendicular to the plane A B E, and the two right lines B F and B F′ will coincide, and the point F will coincide with the point F′. Let this point of coincidence be called G; the point G will be a point in the plane; but the trace A E, and consequently the points A, E are in the plane, hence the sides A G and A E are in the plane. Now, because C D and B E are parallel, and the angle B E G is, by hypothesis, equal to the angle of projection of the line of, which the projection is C D; and because the two planes which contain the lines of which C D and B E are the projections are vertical planes, they are parallel planes.

Hence the right line G E will be parallel to the right line of which C D is the projection; but if a right line be parallel to a right line in a plane, the right line is parallel to that plane; therefore the plane A E G will be parallel to the right line of which the projection is C D.

Projection.

Since a right line is given by having the position of the points in which it terminates, and a plane rectilinear figure by having the position of the right lines which form the edges, a solid bounded by plane figures is therefore given when the points terminating all the right lines which form the edges of its surfaces are given.

Now as a point is most simply determined by its projection and the length of its projectant, so also a solid in space, contained by plain faces, is most simply determined by having the projections and the heights of the projectants of all its linear extremities.

Proposition.—*Problem* 1.

(31.) Any oblique plane, and the position of a point in that plane, being given, to find the horizontal projection of the point.

Let T R (fig. 16) be the trace of the plane, and M the position of the point. Draw M *u* intersecting T R perpendicularly in *v*, and draw *v* W making the angle *u v* W equal to the horizontal inclination of the plane. From the point *v*, with the radius *v* M cut *v* W in *n*, and draw *n m* cutting *u v* perpendicularly in *m*, and *m* is the projection of the point M.

Or, thus:

(32.) Let D be the given position of the point to be projected. Draw D *d* intersecting T R perpendicularly in *g*. In T R take any convenient point *v*, and draw *v u* perpendicular to T R, and make the angle *u v* W equal to the inclination of the plane. In *v* W make *v n* equal to *g* D, and draw *n m* meeting *v u* perpendicularly in *m*. Draw *m d* parallel to T R, and *d* is the projection of D as required.*

Proposition.—*Problem* 2.

(33.) An oblique plane and the projection of a point in that plane being given, to find the position of the point in the plane.

Let T R (fig. 16) be the trace of the plane, and *d* the projection of the point. Having constructed the angle *u v* W, draw *d m* parallel to T R, meeting *v u* in *m*, and draw *m n* perpendicular to *v u* meeting *v* W in *n*. Draw *d* D perpendicular to T R, meeting T R in *g*, and make *g* D equal to *v n*, then D is the point required.

Proposition.—*Problem* 3.

(34.) To find the horizontal projection of the point in which a given right line will meet a given plane.

(35.) *Case* 1. When the given right line is parallel to the plane of projection, it will then be given when its projection is given, and when the projectant of any one of its points is given.

This proposition will be useful when the inclination in the Sun's rays is given, and the inclination of a right line to the primitive plane, to find the shadow of the line.

* For two right lines, one drawn from the point and the other drawn from its projection, will meet the trace of the plane in the same point, and because *g* D is equal to *v* M, the right line D M is parallel to T R; therefore the points D and M are in a right line parallel to the trace of the plane; hence the projections are also in a right line parallel to the trace of the plane; hence the point *d* is the projection of the point D.

Scholium. This last part will be often found convenient, for if many points were to be projected, it would be only necessary to contract one angle for the whole, and thus the unnecessary trouble to construct an angle equal to the inclination of the planes, for every point to be projected would be avoided.

In this case let θd (fig. 17) be the projection of the line, and let T R be the trace of the plane. In T R take any convenient point v, and draw $v u$ perpendicular to T R. Make the angle $u v$ W equal to the horizontal inclination of the plane, and from any convenient point p in $v u$ draw $p q$ perpendicular to $v u$. Make $p q$ equal to the height of the projectant of the point, and draw $q n$ parallel to $v u$, meeting v W in n. Draw $n m$ perpendicular to $v u$, meeting $v u$ in m, and draw $m d$ parallel to T R. Then d is the projection of the point in which the right line will meet the plane of which the trace is T R, and of which the horizontal projection is θd.

(36.) *Case* 2. When the right line is obliquely situated to the horizontal plane, it must be given in this case either by having the projection of two of its points, and the projectants of these two points, or by having the point of coincidence, in which the line meets the plane and the projection and projectant of one of its points.

Let θd (fig. 18) be the projection of the line, θ the point of coincidence, and k the projection of one of its points, of which the projectant is known.

In T R take any convenient point v, and draw $v u$ perpendicular to T R. Make the angle $u v$ W equal to the horizontal inclination of the planes, and draw θl and $k p$ each perpendicular to $u v$, meeting $u v$ in l and p. Draw $p q$ perpendicular to $u v$, and make $p q$ equal to the height of the projectant of the point, of which the projection is k, and draw the right line $l q$. Prolong $l q$ to meet v W in n, and $n m$ perpendicular to $u v$ meeting $u v$ in m. Draw $m d$ parallel to T R, and d is the projection of the point required.*

Proposition.—*Problem* 4.

(37.) To find the point in which a given right line will meet a given plane.

Fig. 19 exhibits the case in which the right line is parallel to the horizontal plane, and fig. 20 exhibits the case in which the right line is obliquely situated to the horizontal plane. The notation or letters of reference being the same as in fig. 17 and 18. Let θk (fig. 19) be the projection of the right line which is parallel to the horizontal plane; find the horizontal projection d of the point in which this right line will meet the given plane. (34.) Again, in fig. 20 let θ be the point of coincidence in which the right line meets the horizontal plane, and let k be the horizontal projection of a point in the line of which the projectant is known; then find (36.) the horizontal projection d of the point in which the right line in this case would meet the given plane. The remaining part of the process being the same for each figure; therefore, in fig. 19 or fig. 20, draw d D perpendicular to T R, intersecting T R in g; then the point n being already found by the construction which was necessary in finding the horizontal projection of the point in which the right line meets the given plane; it only remains to make g D equal to $v n$, and D will be the point in which the right line will meet the given plane, as required to be found.†

Applications of Projection in finding the Sections and Envelopes of Solids.

The surfaces of all solids are developable which can be imagined to be unfolded and extended so that every point in the surface may be in contact with a plane. Or reciprocally, the surface of a solid is developable when a plane surface can be bent upon the surface of the solid so that all its parts may be in contact with the surface of the solid.*

Proposition.—*Problem* 1.

(38.) To find the oblique section and covering of a given prismatic solid, the plane of the section being given.

A prismatic solid is given when the plane which contains the right section is given, and when the section itself is given in relation to the trace of the plane.†

Let $\alpha\,\beta\,\gamma\,\delta\,\epsilon$ (fig. 21) be the given right section of the solid, and let $y z$ be the trace of the plane which contains the right section; also let T R be the trace of the plane which contains the section required to be found.

From the points $\alpha, \beta, \gamma, \delta, \epsilon$ draw right lines perpendicular to $y z$, all meeting it in as many points as there are right lines, and these right lines will be the heights of the projectants of the edges. From the point of section in $y z$ draw right lines perpendicular to $y z$, and these right lines will be the projections of the edges upon the primitive plane. Let θd be the projection of the edge of which δ is the section, and let $\theta\,\delta$ be the perpendicular height of the point δ, and $\theta\,\delta$ will be equal to the projectant.

Find d, the projection of the point in which the right line, whose projection is θd, and the height of its projectant $\theta\,\delta$, meets the plane whose trace is T R and angle of inclination $u v$ W. (34.) (35.) (36.) In the same manner find the projections $e\ a\ b\ c$ of the points in which the remaining edges would meet the plane of section.

Find the point D, in which the right line, of which the projection is $\theta\,\delta$, will meet the plane of section, (37.) and in the same manner find all the other points; then the right lines E A, A B, B C, C D, D E, being drawn, A B C D E will be the section required.

(39.) Let it now be required to find the developement of the successive planes and the edges of these planes which will meet the plane of section upon the right lines A B, B C, C D, D E.

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* For let the plane of the angle $u v$ W be turned upon $v u$ until it become perpendicular to the horizontal plane, and upon this hypothesis, the right line θn, and the right line of which θd is the projection, will be in a plane, of which θl is the trace; and because θl and T R are parallel, the traces of the two planes are parallel; therefore the intersection of these planes is parallel to each of the traces; therefore since n and D are in a right line parallel to T R, the projection of the points n and D are also in a right line parallel to T R.

† The reason of this process is so *obvious*, from that in the preceding proposition, that no demonstration seems necessary to comprehend it. These propositions being understood, the student will find their uses in Carpentry of unlimited application, particularly in the various sections of difficult construction, as will be sufficiently exemplified in this Treatise. We shall therefore proceed to apply them in finding the sections and coverings of such solids as are developable.

* The covering of solids is of the greatest use in Carpentry and Joinery, in forming the soffits of arched doors, windows, or gates; the solids employed in the formation of arches are generally those of cylinders, cylindroids, or of cones, the surfaces of which are always developable.

† This being the case, all the edges of the solid will be perpendicular to the plane of section. But when a right line is perpendicular to a plane, the trace of the plane and the projection of the line upon another plane will be perpendicular to each other, therefore the projections of the edges of the solid in the primitive plane will be perpendicular to the trace of the plane of section. But as it is here supposed that the plane of section is perpendicular to the horizontal plane; therefore the edges of the solid and their projections will be parallel.

* Prolong $z y$ to α'', and at any convenient point α' in the prolongation $y \alpha''$ from $\alpha' \alpha''$ cut off $\alpha' \beta'$ equal to $\alpha \beta$; from $\beta' \alpha''$ cut off $\beta' \gamma'$ equal to $\beta \gamma$; from $\gamma' \alpha''$ cut off $\gamma' \delta'$ equal to $\gamma \delta$; and from $\delta' \alpha''$ cut off $\delta' \epsilon'$ equal to $\delta \epsilon$; and, lastly, make $\epsilon' \alpha''$ equal to $\epsilon \alpha$.

From the points α', β', γ', δ', ϵ', α'', draw the right lines $\alpha' a'$, $\beta' b'$, $\gamma' c'$, $\delta' d'$, $\epsilon' e'$, $\alpha'' a''$, each perpendicular to $\alpha'' a'$; and from the points a, b, c, d, e, in the projection of the section, draw the right lines $a a'$, $b b'$, $c c'$, $d d'$, $e e'$, $a a''$, parallel to $z a''$. Join $a' b'$, $b' c'$, $c' d'$, $d' e'$, $e' a''$, then will the covering required be the rectilinear figure $a'' a' a' b' c' d' e' a''$.

Fig. 1, pl. ii. exhibits another example in which the figure of the solid is a semicylinder instead of a prism.

Proposition.—*Problem* 2.

(40.) To find the envelope or covering of a right semicone, the axis being situated in the horizontal plane.

Let $a b c$, pl. ii. fig. 2, be the section of a cone along its axis, and let $b c$ be the section of the base, then the sides $a b$ and $a c$ of this section are equal to each other, and each equal to any edge whatever of the cone; and consequently, the envelope or covering will be the sector of a circle of which the radius will be equal to any edge of the cone, and the length of the arc equal to the semicircular arc of the base; therefore, upon $b c$ as a diameter describe the semicircle $b f c$, and from the summit a of the cone with the length $a c$ of one of the edges describe the arc c F B, and make the arc c F B equal to the semicircular arc $c f b$. Join B a, and $a c$ B is the envelope required.*

Proposition.—*Problem* 3.

(41.) Given upon the primitive plane a section of a right cone along the axis, the envelope of the semicone, and a point in the envelope to find the projection of that point upon its surface.

Let $a b c$ (fig. 2, plate ii.) be a section of the cone, and let A C B be the envelope of the semicone, and let D be the point in the surface which is required to be projected.

Through the points a and D draw the right line a F meeting the arc c B in F, and upon $b c$ describe the semicircle $b f c$. Transfer the arc c F of the sector to the semicircular arc, making $c f$ equal to c F, and draw $f e$ perpendicular to $b c$. Join $e a$, and from the point a as a centre, with the distance a D, describe the arc Dg meeting $a c$ in g. Draw $g d$ parallel to $c b$, meeting $e a$ in d, and d is the projection of the point D.†

Proposition.—*Problem* 4.

(42.) Given the projection of a point in the surface of a right cone upon a section passing along its axis, to find the position of the developement of the point.

Suppose the cone to be placed upon the horizontal plane, so that its section along the axis may coincide with the horizontal plane.

Let $a b c$, fig. 2, be the section along the axis, $b c$ being the section through the circular base, and consequently a diameter of this circle, and let d be the projection of the point upon the section $a b c$.

Join $a d$, which prolong to meet $b c$ in e, and upon $b c$ as a diameter describe the semicircle $b f c$. Draw $e f$ perpendicular to $b c$, and from a as a centre with the distance $a c$ describe the arc c F. Make the arc c F equal to the portion $c f$ of the semicircular arc $c f b$, and join F a. Through d draw the right line $i g$ perpendicular to A H, the axis of the cone meeting the side $a c$ in the point g, and again from the centre a, with the distance $a g$, describe the arc g D meeting a F in D; then D is the developement of the point of which d is the projection.

Proposition.—*Problem* 5.

(43.) To find the section and envelope of the portion of a right cone comprised between the horizontal plane passing along the axis and a given oblique plane.

Let $\theta l a$ (fig. 3) be the section of the cone along the axis, and let T R be the trace of the cutting plane, and let θl, θa meet T R in l and a.

Bisect the angle $l \theta a$ by the right line θd, and through any point in θd draw $y z$ perpendicular to θd, meeting θl in y and θa in z. Upon $y z$ as a diameter describe the semicircle $y i z$, and divide the semicircular arc into as many equal parts as there are intended to be points found in the section or in the curve of the envelope. Draw right lines through the points of division to meet $y z$ perpendicularly, and through the points of section in $y z$ draw the right lines θb, θc, θd, &c.; then θ is the point where the right lines θb, θc, θd, &c. meet the horizontal plane, and the perpendiculars to $y z$ are the projectants of the points in the semicircular arc. Therefore the projection and the projectant of a point in every one of the lines of which the projections are θb, θc, θd, &c., are given, as well as their common intersection at θ, to find the projection of the points in which these lines will meet the horizontal plane, (34.) (35.) (36.) and to find the points in which these lines will meet the plane of section, (37.) the trace and horizontal inclination of the cutting plane being given. Let b, c, d, &c. be the projections of the points where the right lines forming edges of the conic surface would meet the plane of section, and B, C, D, &c. the points of section of these right lines and the cutting plane; then by the last Problem (42.) find b', c', d', &c., the developement of these points of which the projections are b, c, d, &c., and the curve a B C D, &c. will be the section; moreover, the curve will be the curve of the section of the developement.

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* For imagine the semicone to be so placed, that the sides of the section through the axis may be upon $a b$ and $a c$, and the diameter upon $b c$, and imagine the semicircle $b f c$ to be turned upon $b c$ as an axis until its plane coincide with the semibase of the cone; then as the centre of the semicircle $b f c$ coincides with the base of the cone, the two semicircumferences will coincide and become one semicircumference. Imagine, then, that the sector $a c$ B is to bent that every point in the surface of the cone will coincide with the surface of the sector; then because every right line drawn from the point a to the arc C F B is equal to every right line on the cone's surface drawn from the summit a to the semicircumference of the base, the arc of the sector will coincide with the semicircumference of the base of the cone, and therefore the cone will be entirely covered.

† For suppose the semicone to be enveloped with its envelope, then upon this hypothesis the right line $e f$ will be perpendicular to the plane $a b c$; therefore every plane passing through $e f$ will be perpendicular to the plane $a b c$; hence the plane passing along the right lines $a e$ and $e f$ will be perpendicular to the plane $a b c$; therefore the right lines $f a$ and $e a$ are in the same plane.

Again, since the section of a cone parallel to its base is a circle perpendicular to the axis of the cone, the section of the semicone will be a semicircle perpendicular to the axis; hence $g d$ a part of the diameter, and the arc of the semicircular section are both in the same plane, and since the semicircular section is perpendicular to the axis, all right lines drawn from a to the semicircular arc are equal. Now, since by hypothesis the point F coincides with f, and the right line a F with $a f$; therefore the point D will be in the right line $a f$, and because a D is equal to $a g$, the point D will be in the semicircle of which the diameter is $g i$; hence the points d, D will be both in a right line perpendicular to the plane $a b c$; therefore d is the projection of the point D.

PROPOSITION.—*Problem* 6.

(44.) To find the envelope of an oblique pyramid, given the base, the projection, and projectant of the vertex upon the horizontal plane.

Let $a\,b\,c\,d$ (fig. 4) be the base and e the projection of the vertex. Then the figure $f a' b' c' d' a''$, which is the envelope, may be found by (25.) fig. 13. But as this is of considerable importance in the Art of Carpentry, we shall give the description here; the point e in this being the point g in that of fig. 13, and being common to all the sides $a\,b$, $b\,c$, $c\,d$, $d\,a$ of the base, will render the description easy.

Draw any right line $e\,k$ through the point e.

From the point e as a centre with the radii $e\,a$, $e\,b$, $e\,c$, $e\,d$, &c., describe the arcs $a\,h$, $b\,i$, $c\,k$, $d\,l$, meeting $e\,k$ in h, i, k, l.

Draw $e\,f$ perpendicular to $e\,k$, and make $e\,f$ equal to the height of the projectant of the vertex upon e. Then from the point f as a centre, with the distances of the point f from each of the points h, i, k, l, describe the arcs $h\,a'$, $h\,a''$, $i\,b'$, $k\,c'$, $l\,d'$, and in the arc $h\,a'$ take the point a'' at pleasure; then from the centre a' with the side $a\,b$ of the base cut the arc $i\,b'$ in b', from the centre b', with the side $b\,c$ of the base cut the arc $k\,c'$ in c', from the centre c' with the next side $c\,d$ of the base cut the arc $l\,d'$ in d', and from d' with the remaining side $d\,a$ of the base cut $h\,a''$ in a''. Join $a'\,b'$, $b'\,c'$, $c'\,d'$, $d'\,a''$, also join $f\,a'$, $f\,a''$, and $f\,a'\,b'\,c'\,d'\,a''$ will be the envelope required.*

PROPOSITION.—*Problem* 7.

(45.) Given the radius of a cylindric surface, to find the envelope of one of the portions of this surface comprised between two planes intersecting each other, so that the common section and one of the planes may each be perpendicular to the axis.

Let S T (fig. 5) be the axis of the cylinder.

Method First.

From any point D in S T draw D C perpendicular to S T, and make D C equal to the radius of the cylinder. Through C draw R U parallel to S T, and draw D E, making the angle C D E equal to the inclination of the planes. Let D E meet R U in E. From the point D, with the radius D C, describe the quadrantal arc A B C, and prolong D C to A′. Make the right line C A′ equal to the length of the arc A B C, and divide the arc A B C, and the right line C A′, each in the same proportion, or equally into an equal number of parts. At the points 1, 2, 3, &c. of section in the arc draw right lines perpendicular to D C; and from the points of section in D C draw right lines again perpendicular to D C to meet D E. Likewise, from the points of section in A′ C draw right lines perpendicular to A′ C, and make the perpendiculars from the points of section respectively equal to the perpendiculars comprised between the right lines D C and D E, so that the perpendiculars receding from A′ towards C may be respectively equal to the perpendiculars receding from D towards C.

Thus, for example, from the second point of section II, in the arc A B C, draw $2\,p$, meeting A D perpendicularly in p, and draw $p\,m$ perpendicular to C D, meeting E D in m. From the corresponding second point P, in the right line A′ C, draw P M perpendicular to A′ C, and make P M equal to $p\,m$. A sufficient number of points being thus found, and the curve A′ M′ E′ drawn through these points, the triangle A C E formed by the right lines A′ C, C E, and the curve A′ M E will be half of the envelope required.

But if the abscissas be increased beyond a quadrant, the ordinates will become less and less in reverse order; and when the abscissa is equal to the semicircumference of the circle, the figure will end in an opposite vertex or point.*

Def. Any portion of the sinic figure contained by an ordinate and abscissa, and therefore the part next to the vertex, is called the *vertical segment of the sinic figure.*

Def. Any portion of the sinic figure comprised between two ordinates is called a *truncated sinic figure.*

Def. If the abscissa of the sinic figure be a quadrant, the figure is called a *semi-sinic figure.*

(46.) Hence we have another method of describing the sinic curve.

Method Second.

Let C A′, fig. 6, be the abscissa for half the length of the curve, and C E the middle ordinate perpendicular to C A′. Prolong A′ C to G, and from the centre C, and with the radius C E, describe the quadrantal arc E G. Divide the arc G E into any number of equal parts, and divide A′ C into an equal number of equal parts. From the points 1, 2, 3, &c., in the arc G E, draw the sines of the arcs G 1, G 2, G 3, &c.; and through the points of division in the right line A′ C draw right lines perpendicular to A′ C. Make the perpendiculars upon A′ C, as they recede from A′, equal to the sines of the arcs in the arc G E as they recede from G; then the curve A′ M E, drawn through all the unconnected extremities of the perpendiculars, will be the sinic curve required.

Def. If two sinic figures have the same abscissa in common and equal ordinates, these two sinic figures are called a cylindric right gore, as the fig. F A′ E.

Def. The figure comprised between two sinic curves which have a common abscissa, but the ordinates of the one less than those of the other, whether the curve be upon the same or on contrary sides of the abscissa, is called an oblique cylindric gore. Such is F N A′ M E, (fig. 6.)

PROPOSITION.—*Problem.*

(47.) To describe an oblique cylindric gore, the diameter of the cylinder being given, and the inclination of the axis to each of the planes.

* *Scholium.* In this manner we may approximate to the surface of an oblique cone, or that of any oblique pyramid, whatever may be the number of its sides.

* *Scholium.* The figure thus described is called the *sinic figure.* For if any succession of arcs be taken upon the circumference A B C, from the point A as their origin, as A 1, A 2, A 3, &c., the sines of these arcs will be the right lines drawn from the points 1, 2, 3, &c. perpendicularly upon the radius A D, and will be equal to the portions of the right line D C, intercepted between the point D as their origin, and the points of section of the perpendiculars drawn from 1, 2, 3, &c., upon D C. Thus, let the portion of the quadrantal arc A B C be A 2. Draw $2\,p$ perpendicular to D C, meeting at p. Again, let A 1 be a smaller portion of the arc, and draw $1\,q$ perpendicular to D C, meeting it in q. Draw $p\,m$ and $q\,r$ each likewise perpendicular to D C, meeting D E in m and r. Now D p and D q are the sines of the arcs A 1, A 2; but, by similar triangles, D p m and D q r, we shall have this analogy, D p : D q :: $p\,m$: $q\,r$; that is, $p\,m$ and $q\,r$ are to one another as the sines of the arcs A 2 and A 1; therefore, as the abscissas A 1, A 2, in the plane figure C A′ M E are equal to the arcs A 1, A 2; and, as the ordinates 1 Q and P M in the plane figure C A M E are equal to $q\,r$ and $p\,m$, the ordinates 1 Q and P M are proportional to the sines of the corresponding arcs A 1, A 2 of the right section of the cylinder.

Let ST (fig. 7) represent the axis. Make the angles TDE and TDF equal to the inclination of the two planes, and draw DC perpendicular to ST; in DS make DA equal to the radius of the cylinder, and describe the quadrantal arc ABC. Proceed with each of the plane curves A′ME and ANF, as in (45.), and the figure FNA′ME will be that required.

PROPOSITION.—*Problem* 8.

(48.) To describe a cylindroidal oblique gore for one quarter of the cylindroid, the vertex of the curve being in the extremity of the axis major of a right section of the cylindroid, the two axes of the right section being given.

Let ST, fig. 8, be the projection of the axes of the cylindroid upon the horizontal plane to which the axis itself is parallel, and let TDE and TDF be made equal to the angles of inclination of the axis of the cylindroid to each of the two planes which comprise between them the portion of the surface of the solid; which, (portion of the surface,) when developed, will form the cylindric gore required.

Draw DC perpendicular to ST. Join DS, make DA equal to the semiaxis minor, and make DC equal to the semiaxis major of the ellipse of the right section of the cylindroid. Having described the elliptic quadrant ABC, proceed in the same manner as in the last proposition for fig. 8, and we shall have the spheroidal gore required.*

PROPOSITION.—*Problem* 9.

(49.) To describe the gores in order to approximate to the covering of a spherical surface.

Conceive the sphere to be divided into a number of equal parts by planes intersecting each other in one common diameter of the sphere, then each of these equal parts or sectorial solids are contained by three distinct surfaces, of which the figures of two are semicircles, and the remaining one is called a spherical *lune*.

Let a plane bisect the dihedral angle, contained by the two semicircular faces of one of the sectors, and its intersection with the spheric lune will be the semicircumference of a great circle; now let a plane surface be so bent and applied to the spherical lune that every point in the intermediate semicircumference may coincide with the surface thus applied, and if the surface thus applied be cut by the planes of the two semicircular faces, the portion thus intercepted of the surface applied will be a portion of a cylindric surface,† and will be the nearest approximation to the surface of the spherical lune; therefore, to construct a surface which shall be the nearest possible approximation to the entire surface of the sphere, we have only to form the figure of the developement of one of the cylindric parts, which being done, will serve as a mould in drawing the remaining parts, the whole being bent and fixed together so that the vertices may meet, and the adjacent edges come in close contact; then a cylindric polyhedron consisting of as many obtuse angles as there are parts will be formed, and this polyhedron, if the number of cylindric parts be many, will not differ in any perceptible degree from that of the spherical surface.

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Fig. 9 exhibits the great circle of the sphere with the divisions, and also the figure of one of the parts in developement; the letters of reference are the same as in fig. 5, which is only required to be understood in order to understand this.

PROPOSITION.—*Problem* 10.

(52.) To find the covering of the surface of a spheroid approximately, the fixed and revolving axes being given.

Because if a spheroid be cut by any plane whatever through the centre, a cylindroidal surface may be so

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* *Scholium.* The envelopes of cylindrical, prismatical, conical and pyramidical bodies may be correctly found in one plane figure; but the surface of a nondevelopable solid cannot by any means be unfolded into a plane surface, nor can the figure be altered without breaking it in all parts. Such are the surfaces of conoids which, in course, include those of spheres, spheroids, &c.

† PROPOSITION.—*Theorem* 1.

(50.) All right lines drawn through any given points in the circumference of a great circle of the sphere perpendicular to the plane of that circle, are tangents to the spheric surface at these points, and are in a cylindric surface of which the great circle is a right section.

For, let a diameter of the sphere be drawn perpendicular to the plane of this circle, (which let be called the primary circle,) and the diameter the axis of the primary circle; and let another great circle pass through any one of the given points in the circumference, and through the poles of the primary circle, and let this circle be called a secondary or meridional circle; the circumference of the secondary circle will be divided into four equal parts by the axis, and by the circumference of the primary circle. Now because in any semicircle whatever a right line drawn through the point of bisection in the arc parallel to the diameter is a tangent to the curve at this point; therefore a right line drawn parallel to the axis which is the diameter of the secondary circle of the sphere through one of the points in which the two great circles intersect, will be a tangent to the circumference of the secondary circle at the same point, and since this tangent is parallel to the axis it is perpendicular to the plane of the primary circle. Then, since a right line which is a tangent to a great circle at any point, is also a tangent to the spheric surface at the same point, hence a right line drawn through any given point in the circumference of a great circle of a sphere perpendicular to the plane of that circle, is a tangent to the spheric surface; and as the same may be proved of every right line drawn in the same manner, hence all right lines drawn through any given points in the circumference of a great circle perpendicular to the plane of that circle, being tangents to the spheric surface and perpendicular to the plane of a great circle, are in a cylindric surface of which the great circle is a right section.

PROPOSITION.—*Theorem* 2.

(51.) If two or more great circles intersect a minor circle and intersect each other in one common diameter of the sphere, and if this diameter pass through the centre of the minor circle as its axis, all the tangents to the great circle at the points in which their circumferences intersect the minor circle are tangents to the spheric surface at the same point, and are all in the surface of a right cone of which the minor circle is the base.

For all semi-great circles of the sphere are equal, therefore the semicircles which have the axis of the minor circle for their common diameter are equal; and because the plane of the minor circle will intersect the surface of every semicircle in a right line perpendicular to the axis as an ordinate, hence all the ordinates of the semicircles will be equal, being drawn from the same point in the common diameter; hence all the angles formed by the tangents to the semicircular arcs at the extremities of the ordinates are equal; and because the axis is at right angles with every ordinate, and that the angles formed by the ordinates and the tangents are acute on the side of the minor circle to the nearest pole, and since the tangents and the axis are in the same plane, the tangents will necessarily meet the axis and form as many right angled triangles as there are tangents; but as any one of these right angled triangles has two angles, and the interjacent side, respectively equal to two angles and the interjacent side of any other, all the right angled triangles are equal, therefore all the sides opposite to the equal angles are equal; hence all the hypotenuses are equal, and the perpendiculars opposite the angles contained by the ordinates and the tangents are equal; and since they coincide with the axis line, and have one common extremity at the points in which the ordinates intersect, the other extremities will also coincide in a common point; hence all the tangents are in the surface of a cone, of which the base is the minor circle, and the axis the intercepted part of the axis of the minor circle and the conic surface, is a tangent to the spheric surface at every point of the circumference of the minor circle.

formed and applied to the spheroidal surface, that the two surfaces will only come in contact in every point of the curve of the section of the spheroid.*

The entire ellipse, fig. 10, is a section through the axis of the spheroid, the curve is divided into equal parts and right lines are drawn to the centre; these right lines are the projections of the joints in which the boards meet each other. If every two adjacent lines be prolonged to meet a tangent to the intermediate curve parallel to the chord, the triangles thus formed will be the projections of half the gores. To find the dimensions of the spheroid for any particular gore or part, the semi-axis minor of the spheroid will also be the semi-axis minor of the cylindroid for every gore whatever; and for any particular gore, draw a right line from the centre perpendicularly upon the tangent, or tangent prolonged, and the length of this perpendicular will be the semi-axis major. Thus let the projection of one of the gores be D E F. Prolong E F to C, and draw D C perpendicular to E C, and D C is the semi-axis major. The method of forming the gore is given (48.) and applies here also, the letters of reference being the same in both; the gore being found is here exhibited by the figure E F N A' M E, as in fig. 8.

Another Method.

(54.) Let the circle A B C H (fig. 11) be a great circle of the sphere, and let C O be a radius of the same. Draw the diameter H B at right angles to A O, and divide the arc C H into a number of equal parts, C *d*, *d e*, *e f*, *f g*, &c., so that the chords may be very small. Draw the right lines *d d'*, *e e'*, *f f'*, *g g'*, &c., parallel to the diameter H B to meet the opposite part of the circumference, and because A B C H is a great circle of the sphere, its plane will pass through the centre. Let the sphere be cut by planes through the points *d*, *e*, *f*, *g*, &c., perpendicular to the radius C O, and the curved surfaces of the parts will very nearly be the frustums of conic surfaces, and the sections of these solids through the axis are the surfaces comprised by the parallel right line *d d'*, *e e'*, *f f'*, &c. Therefore, if O C be the axis, join *d* C, then *d* C is the radius of the sector which will cover the surface of the sphere, of which the triangle *c d d'* is the projection, or which will cover the surface of the part of the solid of which *c d d'* is a section through the axis.

Prolong O C to any convenient length, and join *d c*, *e f*, *f g*, &c.; also prolong *e c*, *fe*, *g h*, &c., to meet the prolongation of the axis D C in the points *k l m*, &c.; the right lines *c k*, *d k* are equal to the distance of the vertex of the cone to the circumference of each end of the conic frustum, and of which a section through the axis is *d d' e' e*, therefore, from the point *k*, with the radii *k d*, *k e*, describe the arcs *d q*, *e r*; then the figure *e d q r* is a part of the covering of the surface of the conic frustum of which the section is *d e e' d'*. In like manner the coverings of the remaining frustums may be found.†

Application of Cylindric and Conic Surfaces to the Soffits of Doors and Windows.

Def. A soffit is the lower surface, or intrados, of the part of a wall suspended over the aperture of a door or window between the jambs.

We shall treat only of such soffits as are the under surfaces of arches, and those only which are developable, and therefore easily described in plano.

PROPOSITION.—*Problem* 1.

(55.) To find the developement in the construction of a cylindric soffit, perforating a straight wall, so that

* (53.) For let the section through the centre be called A, and let a section through the axis, perpendicular to the plane of the section A, be called B, and let a third section, parallel to the section B, be called C. Then the sections B and C will be cut by the section A in right lines, which will be parallel to each other, and will be diameters to the ellipses of the sections B and C; therefore since all parallel sections of a conoid are similar figures, and have their corresponding diameters parallel, the tangents at the extremities of these diameters will be parallel to each other. Now every right line which is a tangent to the curve of any section of a solid, is also a tangent to the surface of the solid, therefore the two parallel right lines which are tangents to the curves of the sections B and C, are also tangents to the surface of the spheroid: but the same two points of contact in the curves of the sections B and C, are also points in the curve of the section A; therefore the two parallel right lines, which are tangents to the spheroidal surface, have only their points of contact in the curve of the section A. In the same manner it may be proved that any other right line which passes through any other given point in the curve of the section A, parallel to tangent to the curve in the section B, is a tangent to the surface of the spheroid; hence if these tangents be ever so numerous, being all parallel, they are in the surface of a cylindroid, which will touch the spheroidal surface only in every point of the curve of the section A.

Scholium. Another method of finding the coverings of solids of revolution, is by supposing in any such solid that it is divided into a great number of parts by planes perpendicular to the axis of rotation, so that the chords of the curb surface may be all equal and very narrow, the spherical surfaces of the frustums will not differ sensibly from the surface of the frustums of right cones which are developable. Now as the covering of every right cone is the sector of a circle, of which the radius is equal to an edge of the cone, and the length of the arc of the sector equal to the circumference of the base of the cone, and because similar cones have their angles of developement, that is the angles of their sectorial coverings equal; and since the frustum of a cone is the portion of a cone that remains after cutting off the part next the vertex by a plane parallel to the base, and as the part thus cut off is a cone similar to the whole cone.

Therefore, if the angle of developement of a right conic surface be found, the truncated sector which will cover any given frustum of this cone will be found, by describing, from the vertex of the angle of developement, with radii respectively equal to an edge of the whole cone and equal to an edge of the part cut off, two arcs, then the four-sided figure contained by the two arcs, and the portions of the right line forming the angle of developement intercepted by the arcs, is the covering required.

But, since the edges of a right cone are equal, any edge of such cone is equal to the hypotenuse of a right angled triangle, of which one of the legs is equal to the axis of the cone and the other equal to the radius of the circular base; therefore, in order to find the radius of the sectional covering from the given cone, we have only to construct such a triangle, or two such triangles being joined so that they may have a common leg equal to the length of the axis, will form an isosceles triangle, of which the hypotenuse will be the equal sides, and the two remaining legs will be equal to the diameter of the circular base.

The isosceles triangle thus constructed will be equal to a section of the cone through its axis. We shall now apply the principles of describing the covering of cones, or of their frustum, to the coverings of spherical surfaces.

† These methods of covering a spheric surface may be distinguished by the names of the cylindrical and conical principles, as in the former case we approximate to the spherical surface by means of cylindrical surfaces, and in the latter we approximate to the spherical surface by means of conic surfaces; the conic method is the most easy in its general application, the principle is the same whether the solid be a sphere or a spheroid or conoid, so that the solid may be divided by planes perpendicular to the axis of rotation. The conic method, however, requires more materials to cover the solid than the cylindric method; and in the most useful solid, which is the sphere, its application is abundantly easy; since when one figure is formed, the remaining ones may easily be described without constructive lines, only employing that which was found by a construction as a mould.

the axis of the cylinder may be parallel to the horizon, and in any given position in respect of the plane of the surface of the wall, the radius of the cylinder and the thickness of the wall being given.

Let the parallel right lines B C, A D (fig. 12) be the intersections of the faces of the wall, with a plane parallel to the horizon. Draw the right line B A so that the angle C B A may be equal to the angle which the axis of the cylinder makes with the plane of the wall, and prolong A B to any convenient point E. Draw E G perpendicular to A E, and make E G equal to the diameter of the cylinder. Draw G D parallel to E A, meeting B C in C, and upon E G as a diameter describe the semicircle E H G. Prolong G E to I, and make E I equal to the developement of the semicircular arc E H G. Divide the semicircular arc E H G and its developement E I each into the same number of equal parts, and draw right lines through the points of division in the semicircular arc to meet the base E G. From the points of section in E G draw right lines parallel to G D or E A, to intersect B C and to meet the right line A D, and from the points of division in E I draw right lines also parallel to E A, and consequently perpendicular to E I. Find points in the parallels drawn from the points in E I by transferring the parallels comprised between the right lines E C and E G, so that the distances as they recede from A E on each side of it may be respectively equal, and through the points of division marked upon the parallels draw the curve K L B. In the same manner find the curve M N A and join K M, then K L B A N M is the developement of the cylindric intrados or soffit required.*

Def. A surface is said to be perpendicular to a plane when a right line, drawn from any point in the intersection or trace of the surface perpendicular to the plane, coincides in all parts with the surface.*

PROPOSITION.—*Problem* 2.

(56.) The plane of a circular wall being given, the radius of a cylindrical soffit, and the direction of the axis of the cylinder in a horizontal plane, to describe the developement of the soffit.

Let A E C and B F D (fig. 13) be the plans of the faces of the walls, and let them be parallel arcs of circles; then the two faces of the walls will be concentric, cylindric surfaces having their axis perpendicular to the plane of the horizon, that of the aperture being parallel to the horizon. Let G F be the direction of the cylindric surface of the aperture passing through the axis of the faces of the cylindric wall. Draw A B and C D each parallel to G F, and at a distance from G F equal to the radius of the cylindric soffit, and draw the chord C A of the arc of the concave side of the plan of the wall. Then A B F D C may be supposed to be a horizontal section of the cylindric part of the intrados of the arch through the axis upon which the soffit is to be formed. Upon A C as a diameter describe the semicircle A H C, and prolong C A to I. Make A I equal to the developement of the semicircular arc A H C, and divide the arc A H C and the right line A I, each into the same number of equal parts.

Through the points of division in the arc A H C draw right lines perpendicular to A C to meet it in as many points as the perpendiculars are in number; and from all the points of section in A C draw right lines parallel to A B, intersecting the curve A E C, and meeting the curve B F D each in as many points as the number of lines which are parallel to A B, drawn from the points of section in A C. Through the points of division in A I draw right lines parallel to A B, and upon each of these right lines receding from A set off the respective

* In order to prove the truth of this, it is only necessary to show that the developement will, when properly bent, coincide with the cylindric surface, and its edges with the two planes which are perpendicular to the plane of the axis of the cylinder, and which are the faces of the walls.

The following are the propositions in which the demonstration depends, viz.

Every right line which is parallel to the plane of projection, is projected into a right line equal to its own length.

Every right line and its projection are in a plane perpendicular to the plane of projection.

Every point which has a projection is in a right line perpendicular to the plane of projection drawn from the projection of the point.

Now, since the plane of projection contains the axis of the cylinder, and all the right lines on the curved surface of the cylinder are parallel to the axis, therefore all right lines upon the surface of a cylinder are projected upon a plane which contains the axis, into right lines of equal length and also parallel to the axis.

Let the plane of the semicircle E H G be raised upon the right line E G perpendicular to the axis, and suppose the semicylinder to be placed upon the section so that the axis may be upon F B, and the centre of the semicircular base upon the point F; then the semicircumference E H G will coincide with the semicircumference of the end or base of the cylinder.

Then, because if in the plane of developement two right lines form a right angle, and if one of them be applied so as to coincide with any edge of a cylinder, and if the plane of developement containing them be bent upon the cylindric surface so that all the points of the two surfaces shall coincide, then the other right line will fall upon the circumference of a circle which will be a right section of the cylinder.

Moreover, if two right lines in a plane are parallel, and if one of these right lines be applied to any edge of a cylinder, and the plane so bent upon the cylindric surface that all the points of the two surfaces may coincide, then the other right line will coincide with another edge of the cylinder.

Therefore, in the developement, since the right line E I is the length of the semicircular arc, and both the right line E I and the semicircular arc divided into the same number of equal parts, and since the right line E I is perpendicular to the edge E B of the cylinder, therefore if the developement A E I M N A be bent upon the cylindric surface, and if all the points in both surfaces be in contact, the right line E I will fall upon the arc of the semicircular base, and the points of division upon the corresponding points of the semicircular arc, and all the right lines which were in the developement will be parallel right lines upon the cylindric surface, and will therefore be parallel to the axis; and as these right lines pass through points in the circumference of the base, and as those points in the circumference of the base are the upper extremities of right lines perpendicular to the plane of projection, and the other right lines drawn in the plane of projection from the foot of the perpendicular are parallel to the axis; hence the right lines upon the cylindric surface drawn from the upper extremities of the perpendiculars, and the lines drawn from the feet of the perpendiculars in the plane of projection, are in planes perpendicular to the plane of projection, *viz.* every two which are drawn from the same perpendiculars are in a plane perpendicular to the plane of projection and parallel to the axis of the cylinder; hence the right lines which are drawn in the plane of projection parallel to the edges of the cylinder, are the projections of the right lines which form the edges of the cylinder, and, since all the points of these edges are equal to the corresponding parts of their projections, all the points in the plane of projection must be the projections of the points upon the cylindric surface; and as the curves pass through these points in the cylindric surface and the right lines which form the faces of the wall pass through, the points in the plane of projection; therefore, the whole developement will coincide with those lines on the cylindric surface of which the projections are given.

* *Scholium.* The following theorems are indispensable, and are almost self-evident of themselves; but, as the last two require many words to connect the chain of reasoning, we shall be under the necessity of omitting the demonstration, and so remain satisfied with the enunciations of the propositions.

Carpentry. distances comprised between the chord A C and the curve A E C. Through the extremities of the distances draw the curve I K A, and, in the same manner, draw the curve L M B, and join I I; then the figure A M B L I K A is the developement of the soffit required.*

Proposition.—*Problem* 3.

(59.) To draw a tangent to either of the curves in the developement of a cylindrical soffit in a straight wall, the axis of the cylinder being parallel to the horizon, but oblique to the face of the wall.

Let it be required to draw a tangent at the point L (fig. 12) in the curve K L B. Draw L s parallel to A E, meeting E I in s, and make the arc E r equal to the right line E s. Draw $r v$, a tangent to the semicircular arc E H G, at the point r; and from any convenient point, v in $r v$, draw the right line $v t$ perpendicular to A E, meeting I E in t. Draw $t u$ parallel to B C, and $r z$ perpendicular to E G, meeting E G in z; also draw $z u$ parallel to E A. Construct, in any convenient situation, the right angled triangle $x y w$, so that the base $x w$ may be parallel to E I and equal to $v r$, and that the perpendicular $x y$ may be equal to $z u$. Through the point L draw J Q parallel to $y w$, and J Q is the tangent required.

Proposition.—*Problem* 4.

(60.) To draw a tangent to either of the curves in the developement of a cylindric soffit in a cylindric wall, the axis of the cylindric surfaces being in the same plane, one parallel and the other perpendicular to the horizon.

This process is in every respect the same as the preceding, except that a tangent must be drawn to a corresponding point in the curve of the plane of the wall; and then the tangent to be used in the same manner as was done in respect of the right line B C. (Fig. 12.)

Let it be required to draw a tangent through the point K (fig. 13) to the curve I K A, which is the developement of the cylindric soffit, and the concave face of the wall. Having drawn $r z$ perpendicular to A C, draw z E parallel to A B, meeting the concave side of the plan of the wall in E; and through the point E draw P Q, a tangent to the circular arc A E C, which is the plan of the wall. Then, having constructed all the parts, and the triangle $x y w$, as in the preceding problem, through K draw J N parallel to $y w$, and J N is the tangent required.† Carpentry.

PRACTICAL CARPENTRY.

Section I.

The practical operations in Carpentry consist in the methods of preparing timbers and in joining them together, so as to effect the end or purpose desired.

Junction of timbers. Timber bars may be extended to any length in a right line, by joining one timber to the end of another as often as may be necessary to make the required length, by cutting the corresponding ends which join, in such a manner that every point of the part cut away in the one will coincide with a corresponding point in the other; in whichever of the two the point is taken. The parts cut away at the two ends of two pieces of timber which join are generally plane surfaces, and the joint ought to be such, that when the two timbers are joined and kept together, two forces applied in a direction of the length of the two pieces thus united, may not be able to pull them asunder without breaking at the joint. Timbers joined in the manner now described are said to be *scarfed*. This will be evident by inspecting figures 13 and 14, which are the simplest forms of scarfing. Scarfing.

Fig. 13 exhibits a plane scarfing, and fig. 14 a scarfing put together with two wedges in such a manner as to draw the joint close together. The timbers of fig. 14, if held together sideways, without any pressure but that which is just sufficient to keep their surfaces straight, could not be drawn from each other, when keyed or wedged, without splitting off some part or other at the joint.

Timbers may also be joined either at oblique or at right angles. The timber bars which form the enclosure of every frame used in building may be rectangular, excepting those which are employed in the different faces of a roof in order to support the covering. There is no reason, however, why the interior timbers of every frame comprised between the sides of the enclosure should not be rectangular. The advantage of rectangular bars will appear manifest from the following consideration: if two rectangular bars have each two faces perpendicular to a plane, and if the two faces of the one which are perpendicular to the plane intersect the two faces of the other which are perpendicular to the same plane, two intersections of these faces will be perpendicular to that plane.‡

Whenever two pieces of timber are joined to form an angle, we shall always suppose that they are rectangular bars, of which two faces are parallel to a plane, and

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Proposition.—*Theorem* 1.

* (57.) If a plane A, and any surface B, be each perpendicular to a plane C, the common intersection of the plane A and the surface B will be a right line perpendicular to the plane C.

Proposition.—*Theorem* 2.

If any right line be drawn parallel to the edge of a plane, which is also a right line, and if the plane be so bent that, when applied to a cylindric surface, the rectilinear edge of the plane may coincide with an edge of the cylindric surface, and the bent surface in all points with that of the cylinder, the other line upon the bent surface will fall also upon an edge of the cylinder, or coincide in all points of it.

Proposition.—*Theorem* 3.

(58.) If in any plane A, passing along the axis of a cylinder without the solid, a point B be so situated that the shortest distance to the nearest edge C of the cylinder may be less than the circumference, and if a right line D be drawn in this plane through the point B perpendicular to the axis; and if the plane be so bent into a curved surface E, and applied upon the cylindric surface, that all the points of the two surfaces may coincide, the position of the point B in the bent surface E will be in another plane F, passing along the right line D perpendicular to the first plane A.

† *Observation.* As the first of these curves in Prob. I. fig. 12, of this section is the developement of the intersections of the surfaces of a cylinder and that of a plane, the method of drawing the tangents to the intermediate points of the curves in fig. 5, 6, and 7, being of the same species, will be the same as here shown. It will only be necessary to give an example of the method of drawing a tangent to the extremity of the curve, fig. 5. In A C make A d equal to D C, and draw $d e$ perpendicular to A C. Make $d e$ equal to C E, and join A e. Then A e is the tangent required. This description will also apply to fig. 6 and 7.

‡ The trusses of a roof are the only frames in a building comprised between parallel planes which have not to support a covering, their office being to support the weight of the roof which presses upon their sloping edges. All timbers in the truss of a roof ought to have each two faces parallel to a given plane, and the other two faces perpendicular to that plane, in order that when they join, the intersections of the faces which are perpendicular to the plane may be in right lines perpendicular to the other two faces.

consequently the other two faces perpendicular to that plane, unless the contrary is expressed; and thus, when one piece of timber is perpendicular to another, if the end of the one piece fit close upon the side of the other, that end must be in a plane perpendicular to any one of the four arrises of that piece.

Every timber in a building which terminates with a close joint upon the face of another, will have its end in the figure of a rectangle, of which two sides will be perpendicular to the plane of the angle formed by these two timbers, except in the faces of hip or in hip and valley roofs, where the ends of the jack rafters and the ends of the purlins meet the hips.

Shoulder joint.

When the ends of a piece of timber join one of the faces of another piece of timber, and form such a joint that all the faces of the piece of which the ends fit upon the other intersect, and form a close joint, these two timbers may be firmly secured to each other by means of nails or bolts, provided that the angle which they form is very oblique. This form of joint is called a *shoulder joint*, and the end of the piece which fits upon the face of the other is called the *shoulder*: but if the directions of the pieces form a right angle, or approach nearly to a right angle, such a method of fixing them cannot be secure, at least where one of them acts as a lever upon the other.

Mitre joint.

Another method of fixing two timber bars at a given angle, is to cut the ends of each of the pieces, so that they may meet each other in a plane perpendicular to the plane of the angle which the two pieces make with each other, and which will either bisect that angle or pass through the intersections of the outer and inner faces of these timbers. This form of joint is called a *mitre joint*, and the two pieces are said to be *mitred*. Here the lengths of the mitring surfaces in both pieces are equal. The pieces which are mitred together may be rendered much more secure by means of nails or bolts, than when they are simply shoulder jointed, particularly when one of the pieces is required to act as a lever upon the other.

Close joint.

One piece of timber may be joined to another by inserting a part of the one into an excavation of the other, or reciprocally by excavating both, and inserting a portion of the solid of the one into the hollow of the other. The surfaces which are thus concealed by being brought into contact are called a *close joint*. A close joint may be made in an infinite variety of ways; by making the hollow of the one in such a manner, that when the two pieces are joined all the points of the surface which were excavated in either piece may come in contact with some point or other of the surface of the other solid. This is an universal method of joining timbers, but the modes by which it may be done are of infinite variety. Generally, whatever may be the office of a piece of timber which is to be fixed to another, the excavation which is cut in the one piece in order to receive a part of the solid of the other, ought to be such that the surfaces may be in planes either perpendicular or parallel to the face of the timber from which the excavation may be made. The particular manner of forming the joint will depend upon the two following cases; *viz.* 1. when one of the pieces is fixed and the other in a state of tension; and 2. when one is fixed and the other in a state of compression. As every timber bar has a considerable weight, it cannot be kept stationary without being supported at least under one point; but the most secure supports will be under its extremities. For whatever be the kind of pressure to which a bar of timber may be subjected, it has also to support its own weight; and thus the formation of the joint of two timber bars to be fixed to each other at a given angle will depend upon the joint consideration of the species of strain and the weight of the timber.

In forming the joint of two timbers making a given angle with each other, we shall always suppose that one of the pieces is fixed or immovable by some means or other, and the species of strain to which the other may be subjected given, and that the fixed piece has to support the other.

Cocking.

The case of tension requires the joint to be made in such a manner, that it would be impossible to pull the piece of which the strain is given out of the fixed piece without leaving a part of the end of the one or the other or of both timbers. The operation of forming such a joint has been called *cocking*, and the piece of timber in the state of tension is said to be *cocked* upon the other.*

Notching. Holving.

When two pieces of timber are of the same thickness, and are required to be joined to each other in the form of a cross, the two parts may be so cut, that when put together they may be comprised between two parallel planes at a distance from each other equal to the thickness of one of the pieces only. This method is called *notching*, and when each of the pieces is reduced to half its thickness, by taking away a rectangular solid equal to half their thickness, the method of notching is called *holving*.

When two timber bars are intended to be joined together in order to form a cross, where one of the pieces is to be let down upon the other, two notches are generally cut from the upper face of the lower bar, by taking away two rectangular solids, and leaving a solid part between the two notches, and one notch is cut from the lower face of the upper bar to fit the piece which remains whole between the two notches in the lower timber bar, so that when the two timbers come to be joined, two ends of the two notches of the lower piece, and one of the perpendicular faces of the upper piece, may be in the same plane, and the remaining ends of

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* The state of compression requires only that the end of the timber may be supported from falling, and that it may coincide in all parts with the face of the fixed timber: therefore any joint that will answer this purpose will be sufficient.

Another consideration in the joining of two timbers A and B together is, 1. when the length of the timber A extends from one of the perpendicular faces of the timber B to any required distance before the opposite face of B, and reciprocally when the length of the timber B extends from one of the perpendicular faces of the timber A to any required distance before the opposite face and thus making two arms which form only one angle.

2. When the length of the timber bar A extends from one of the perpendicular faces to any required distance before the opposite perpendicular face of B, and when the length of the timber bar B extends on both sides of the timber bar A, without dividing it into two parts, and thus making three branches which form two adjacent angles.

3. When the length of the timber bar A extends on both sides of the timber bar B, and the length of the timber B on both sides of A, without dividing either of the timbers A or B into separate parts, and thus making four arms or branches, of which every two will make the opposite angles equal.

The first of these modes is the weakest, the second is stronger than the first, and the third is stronger than the second, and consequently the strongest of the three. In the first, one is said to form an angle with the other, and is called the method of joining at an angle; in the second, one timber is said to stand upon the other, and is called the method of joining at two adjacent angles; and in the third, either timber extends on both sides of the other, and is called the method of the cross.

these two notches in the lower bar in the same plane as the remaining opposite perpendicular face of the upper bar, and that the depths of the notches in both pieces may be equal to the distance intended to be let down.

In plate iii. fig. 15, the figure *e f g h*, No. 1, is a right section of the lower timber; A B C D one of the vertical faces of the upper timber. These exhibit the manner in which the solid part between the two notches of the lower timber fills the notch in the lower side of the upper timber. In No. 2, S T U V exhibits a part of the upper face of the lower bar, with the outlines *i j k l*, *m n o p* of the notches, *w x r q* show the situation into which the upper timber comes.*

Though fig. 15 and 16 are essentially the same in principle, fig. 15 is adapted to the cockings of roofs and floors upon wall plates. Here, as each extremity of a beam must be within the thickness of one of two opposite walls, and the two opposite wall plates are each in the plane of the two interior faces of the two walls, the length of the beam cannot therefore extend over the outside vertical surfaces of each wall plate in any considerable degree, perhaps not more than the breadth of the wall plate itself, if rightly proportioned to the thickness of the wall. In this case the weight of the beams alone, independently of the weight of the incumbent parts of the wall, gives sufficient pressure to keep them in their cockings when they are either pulled or compressed. This is the reason for diminishing the breadth of the solid break *k l p o*, between the two notches in No. 2, fig. 15, and keeping nearer the face in the interior surface of the wall than to the other vertical face inserted in its thickness.†

Though, as has already been observed, fig. 15 and 16, plate iii., are the same in principle, yet with respect to their use, they are adapted to very different purposes. It has been shown that fig. 15 is adapted to the juncture of the tie beams of a roof to the wall plates, and it will now be shown that fig. 16 exhibits the best proportion between the tongue part of the joint, and the notches where the two pieces of timber are joined in the form of a cross in which the upper timber extends before the lower vertical faces to a considerable distance. In this case, as each arm of the upper timber extends before each adjacent face of the lower timber, there can be no danger of splitting away the part between the notch and the extremity; hence the breadth of the tongue *k l p o* between the two notches of the lower piece may be made in the middle of the breadth of the upper face of the lower timber, and of much greater breadth than that in fig. 15, so that each of the two notches in the upper face, No. 2, fig. 16, will be much narrower than the width of the notch *i j k l*, fig. 15; by this means the strength of the piece S T U V, fig. 16, will not be sensibly diminished by the two notches.*

Indeed, if the bridging joists were merely laid upon the binding joists without any notching whatever, the floor would be equally strong as if they had been notched. The only use, therefore, of notching and tonguing is to give the bridging joists a more steady bed upon the binding joists; and this would often be required when the binding joists are bent in the seasoning of the timber, or by taking a curved direction after the operation of sawing.

The proportion between the breadth of the tongue and that of the notches, and the situation of the tongue in regard of the horizontal breadth of the timber, from which it is cut, is not only applied to the joinings between the bridging and binding joists in floors, but also to the joinings between the common rafters and purlins, and between the purlins and principals in roofing.

Fig. 17 exhibits another distinct method of cocking wall plates upon tie beams by dovetail joints. But by this method of forming the joint between two timbers, when the upper timber shrinks the dovetail tongue at the end will also shrink; and thus the joint will open. And hence in the case of an extending force, the upper piece will be liable to be drawn away from the lower piece; but this cannot be the case when the tongue of the lower piece runs across the breadth of the upper piece,

* It is now evident that if the lower bar S T U V were immoveably fixed, and the upper timber bar *w x r q* were kept down upon the lower timber bar S T U V by any sufficient pressure, that it would be impossible to draw the upper bar from the lower one, by any force pulling in a direction of its fibres; but when one of the arms of the upper timbers extends only a very short distance from the adjacent vertical face, as in fig. 15, the part *w x k l* of the short arm underneath, between the notch and the extremity, would be liable to split off: for this reason, the solid part *l k o p* is not only made narrower, but brought nearer to the face adjacent to the long arm, than if both had been long arms, as in fig. 16.

† It cannot be properly said, that when timbers are perfectly straight, any timber bar is either drawn from or compressed towards the wall plate, because the ends of the bar only lie upon the wall plates, and therefore their weight only presses perpendicularly upon them. However, as all timber is liable to bend, and if it bend by not being sufficiently strong, the under edges of the beams will descend from each extremity to the middle in a curve, and will therefore form a wedge, which will endeavour to separate the two opposite walls to a more remote distance, in this respect these beams will be actually drawn in a direction of their tangents to the extremities of the curves upon the under edges of the beams; and not only from this circumstance alone, but even by the walls themselves having a tendency to separate, from being unequally supported at the foundation, or from bad building, by which the walls may contract more upon one side than upon the other. To verify these observations, many floors have fallen down, and this could not have happened unless by the spreading of the walls. There is not so much danger to be apprehended from the tie beams of a well-constructed roof having any tendency of being drawn from the wall plates, as from the binding joists of a floor; for the tie beams may be kept in a right line by being supported in a sufficient number of points, so as to divide the length into equal intervals of short bearings: moreover, the weight of the roof is discharged upon the tie beams in two different directions from each end, so that in each and one direction is perpendicular to the horizon, and the other is parallel to it. The tension of the tie beams is sufficient to resist the force of extension without making any sensible alteration in their length; therefore the only effect which the roof can have, is a perpendicular pressure upon each wall equal to half its weight. The case would be very different if the ends of the principal rafters were supported by the wall plates, instead of being supported by the ends of the tie beams; for if the principals were supported by the wall plates, the wall plates would have a tendency to separate from each other, and nothing could prevent this separation except the cockings at the ends of the tie beams.

* This proportion and situation of the tongue, in respect of the breadth of the upper horizontal face, in which it is situated, as shown in fig. 16, is proper for one of the joints between a bridging and binding joist, as the area of the right section of the binding joist is not diminished in any considerable degree. This case, as the binding joist is only supported by opposite walls, or between a girder and the wall, or between two girders, requires the binding joists to be of the greatest possible strength, and differs materially from the other case, in which the wall plate is in the same situation in respect of the binding joists as the binding joist is with respect to the bridging joist; and in the mode which fig. 15 exhibits, the wall plate is supported in every point by the stone or brick work underneath, which is levelled for the purpose of receiving the lower horizontal face of the wall plate; but as to the binding joist it is quite unsupported except at its extremities, and therefore the less the substance is diminished in any part the resistance which it makes will be greater. If the binding joists are sufficiently strong, any moderate pressure laid upon its middle will not have any sensible effect in drawing the bridging joists, between which it is suspended.

and its being made so very narrow leaves but a very small breadth for shrinkage.*

Mortise. Tenon.

A *mortise* is a recess in the figure of a prism from any face of a piece of timber to any depth, or even entirely through the timber, and a *tenon* is a part left on the end of a piece of timber, proceeding forward generally from a plane surface in the form of a prism, so that one of the parallel ends may be in the plane from which the tenon proceeds, and the other end the extremity of the tenon, and that the remaining faces of the tenon may be parallel to the faces of the timber from which the tenon is made. The apparent part which forms a border round the tenon is called the *shoulder* of that tenon.

Shoulder of a tenon.

One piece of timber may be joined to another by means of a mortise and tenon adapted to each other so as to have a close joint; hence the shoulder of the tenon will coincide with the face of the other timber from which the mortise is recessed, and because the timbers are generally rectangular bars, and when one bar is joined to another, the tenon if cut through in the same plane with the shoulder will be a rectangular parallelopiped. The manner of joining rectangular bars by means of a mortise and tenon is of excellent use where it is required to confine a piece of timber between two others which are firmly supported, and the piece between only to be supported by these timbers, considering it either in a state of compression, or by being strained transversely by a force.†

SECTION II.

A frame consisting of timber bars so constructed that every bar may be divided longitudinally by a plane into two symmetrical parts, and that the section of the frame made by this plane may also consist of two symmetrical parts on each side of a right line perpendicular to the section of one of the outer edges called the base; moreover, that if two extremities of the base be supported, and if forces be applied so as to act at certain other points upon the surrounding edges of the frame in the bisecting plane, and in right lines perpendicular to the base, and that the number of these points on the one side of the perpendicular may be equal to the number of points on the other side, and that every pair of such points may be in right lines parallel to the base, and equally distant from the perpendicular, and that the forces upon every two corresponding points may be equal, and that the effects of these forces may not have any tendency to produce a transverse strain on any part of the frame; such a frame is called a *truss*.

Truss.

Points of suspension.

The two fixed points, one at each extremity of the base, are called the *points of suspension*, and the remaining points, on which the forces act so as to keep the frame in equilibrium, are called *truss points*.

Truss points.

Plane of the truss: Line of symmetry. Plane of symmetry.

The plane which bisects the timbers is called the *plane of the truss*, and the perpendicular which divides the truss into symmetrical parts is called the *line of symmetry*; moreover, a plane passing along the line of symmetry perpendicular to the plane of the truss is called the *plane of symmetry*; and thus the plane of symmetry divides the truss into two equal parts.*

Each of the two points of suspension of every truss is in the under horizontal face of the tie beam, near the extremity of that face, and rests immediately upon the wall plate.

The tie beam of every truss in a roof ought to be

* The method of rectangular notches, and a rectangular tongue, of which the apparent sides are parallel to the sides of the timber, is of very late introduction, perhaps not more than sixty years. The principle of notching with square abutting joints, has always been much adhered to by the best Carpenters since its first introduction: but its advantages over the dovetail joint in not admitting the upper piece to be drawn out of the lower piece when the timber is shrunk, was, we believe, first noticed by Mr. Peter Nicholson.

† The method of joining two timbers by means of mortise and tenon is that which is applied to the trusses of roofs at the joggles, and in fitting the upper ends of the struts into the inner or under edges of the principal rafters. This mode is also frequently applied to truss partitions, similarly to its application in the trusses of roofs; moreover, the joining of timber bars by means of mortise and tenon is also applied in naked flooring in connecting the trimmers to the trimming joists, as also, with a slight modification, to connecting the binding joists with the girders. The only difference in this application from common mortise and tenon being in the shoulder of the tenon, in which the upper part is made to slope towards the tenon in such a manner, that the upper surface of the tenon and the part of the shoulder above it may form an internal obtuse angle, equal to the external angle made by the same part of the shoulder of the tenon and the upper horizontal surface of the binding joist. This sloping part of the shoulder of the tenon upon the end of the binding joist is called *tusk*, which is let into the girder with a view of giving a stronger support to the tenon, which is generally made thin in order to preserve the substance of the girder as much as possible.

The method of connecting the ceiling joists with the binding joists is a species of mortise and tenon. In the ceiling joists the shoulder of the tenon is generally made adjacent to the under horizontal surface of the ceiling joist, only so that the upper horizontal surface of the ceiling joist and that of the tenon may be in one plane. The tenon formed in this manner is called a *barefaced tenon*. But as the ceiling joists are generally put in after the building has been roofed, and as in this case the binding joists are always fixed, their ends being inserted in the opposite walls, or between two girders, or between a girder and the wall, the mortises must be prepared in such a manner as will admit of the ceiling joists being brought to their places, as if they had been previously formed, into the placing of the binding joists on the building.

To fix the ceiling joists under those circumstances; the mortises must be prepared in such a manner that if we call a close mortise at one end *m*, and at the other end M, and one of the two next adjacent mortises from the same face N; when the tenon is fitted into the mortise *m*, the other tenon when revolved round *m*, as a centre, may find no obstruction in bringing it to its place M, where it cannot be moved further in any direction except backwards. This may be accomplished by cutting away as much of the binding joists which contain the mortises M and N as may be necessary; and this is generally done by cutting away the wood below the mortise M so as to make one long mortise instead of the two M and N, the sides and back of the long mortise being a continuation of the planes of the sides and backs of the mortises M and N. The long mortises which are thus cut in the vertical sides of binding joists are called *pully mortises*, or *chase mortises*.

* The definition which we have given of a truss is such as will be found to apply in many situations; *viz.* in roofs to support the inclined covering; and here also it may be employed in discharging the pressure of the rafters from the intermediate parts of the walls in case that the roof is constructed without tie beams. Trusses are also used in partitions for supporting the floors.

When a truss is employed for supporting the covering of a roof, the bisecting plane of the timbers ought to be in a plane perpendicular to the plane of the roof and in a plane perpendicular to the horizon, and thus the rafters and tie beams will be perpendicular to the wall plates; and when a truss is employed for discharging the pressure of the rafters from the wall plates, and consequently from the walls themselves, the plane of the truss ought to be parallel to the plane of the covering.

If a truss be so constructed that when the line of symmetry is perpendicular to the horizon, and the whole of the timber work situated above the horizontal line; then if in the half of the truss upon one side of the roof, the upper ends of the remaining timbers of the surrounding enclosure be nearer to the line of symmetry than the lower end, such a truss is proper for the truss of a roof.

In the application of trusses to roofing, the truss points will be in the upper inclined edges of the principal rafters, and they ought to divide the lengths of their rafters into equal parts, so that every truss point may support a point of a purlin, and all the truss points in the inclined upper edge of the principal rafter will support one point of every purlin, and all the truss points will support all the equidistant points of every purlin.

supported in a certain number of equidistant points, so that if weights are suspended from these points, the weights thus suspended would not cause a transverse strain in any timber whatever in the construction of the truss.*

Trussing post. King post. Corresponding side posts. Queen posts. Tie beam. Collar beam. Auxiliary rafters.

Every timber bar which forms one side of a triangle, and which is perpendicular to the horizon, is called a *trussing post*. A trussing post in the middle of a truss is called a *king post*. Two trussing posts on each side of the plane of symmetry, and equidistant, are called *corresponding side posts*, and if there be only one pair of corresponding side posts in a roof, such a pair of side posts are called *queen posts:* moreover, if the truss posts consist of more than one pair of corresponding side posts, but have king posts, that pair of corresponding side posts which are at the least distance from each other are called *queen posts*. If a truss have only one beam, that beam is called a *tie beam;* but if it have two beams, the lower beam is called the tie beam, and the upper beam is called the *collar beam*. If the principal rafters are supported upon an independent truss, the timbers in the truss upon which the principal rafters are supported are called *auxiliary rafters*.

Fig. 18, pl. iii. is the elevation of a truss which exhibits the faces of the timbers which are parallel to the plane of the truss, and in their real proportions, T t being the tie beam, P p, P p the two principal rafters, K k the king post; D d, D d queen posts, B b collar beam, E e, E e auxiliary rafters, and S s, S s struts. These are the timbers which constitute the truss. The truss is supported by the wall plates, of which their sections are W, W, fig. 18. The timbers supported immediately by the truss are the pole plates Q q, Q q, fig. 19, the purlins L l, L l, and the ridge piece R r, and lastly, the timbers supported by the pole plates, purlins, and ridge piece are the common rafters, C c, C c. The double letters in the timbers supported by the truss, are only to be found in the perspective view, as also in the wall plates W w, W w.

Section III.

To find the lengths and angles of the timbers of a roof in every position in which they can be placed, is only to resolve the various cases of the right trehedral. It may be proper to observe in this place that those who have previously acquired this knowledge will never be at a loss to solve every difficulty; but those who have not done so, must be contented with the rules by which the particular case in hand may be constructed. We shall here give an example or two of the application of the trehedral, which perhaps will be as much as the practical Carpenter may desire, but which will be of signal advantage to the theorist by showing how the principles are applied in practice.

Example 1. Given the directions T U, U V, V W, fig. 20, pl. iii., of the wall plates of the regular hip end of a ridge roof single inclined upon each side of the ridge piece, and the height of the roof, to find the lengths of the common and hip rafters.

In U T and in V W make U d and V a each equal to the half of U V, and draw the right line $a\,d$. Bisect $a\,d$ in c, and draw $c\,b'$ perpendicular to $a\,d$. Make $c\,b'$ equal to the height of the roof, and join $a\,b'$, $b'\,d$, and $a\,b'$, $b'\,d$ are the lengths of the common rafters.

From a with the distance $a\,b'$, the length of a common rafter, cut $a\,d$ in b, and join V b, and V b is the length of the hip rafter.

Example 2. To find the angles of the backs of the hip rafters.

Join V c, and through any convenient C in V c draw B e perpendicular to V c, meeting V W in B and V U in e. Draw B A perpendicular to V b, meeting b V in A, and from the point B with the distance B A cut c V in A′. Join A′ B and A′ e and B A′ e is the entire hip angle, or the angle of the back of the hip rafter.*

Example 3. The same things being given to find the angles which the upper arrises of a purlin makes with each adjacent arris of the section of that purlin upon the vertical face of the hip rafter.

In $b'd$, the back of the common rafter, let $f\,g$ be the side of a right section of the purlin, and $f\,g\,h\,i$ the entire right section. Join c U, and draw $f\,o$ parallel to U T meeting U c in o. From the point f with any convenient radius describe the semicircle $j\,l\,m\,k$, and draw the diameter $j\,k$ parallel to $d\,a$. Let the semicircle cut $b'\,d$ in l and $f\,i$, prolonged if necessary in m. Draw $j\,r$, $l\,s$, $m\,q$, and $k\,p$ parallel to $f\,o$, and let $l\,s$ and $m\,q$ meet c U in s and q. Draw $q\,p$ and $s\,r$ perpendicular to $f\,o$, and join $o\,p$, $o\,r$; then $n\,o\,r$ and $n\,o\,p$ are the two bevels required.†

The developement or the method of extending the surfaces of a roof in planes are of signal utility in finding the lengths and bevels of all the timbers in these various faces.

Example 4. To describe the covering of a regular hip roof in plano, the plan of the roof being given.

Part 1. Let A B C D, fig. 21, be the plan of the

* The number of trusses in a roof will depend upon the length of the purlins in their extension from gable to gable, or from hip to hip or from hip to valley. The truss points in a roof may be found so that the rafters may be equally divided, or in given proportion, by timbers so arranged as to form two series of triangular openings between the points of suspension, so that the vertex of every triangle of one of the series may be in the under inclined side of the principal rafters, and that the opposite side may meet the vertices of two adjacent triangles of the other series of which the bases are parts of the principal rafter.

* *General observation.* The part of the first example which shows how the length of the hip rafters are found, is the same case of the right trehedral as when there are given the inclination and the adjacent right face to find the oblique face. (7.) Here a V c is the adjacent face, and V a the adjacent edge. Then having assumed the point a in V W, draw $a\,c$ perpendicular to V a, (this is already done, for the point b is either in $a\,c$ or in $a\,c$ prolonged,) and at the point a with the right line $a\,c$ make the angle $c\,a\,b'$ equal to the given inclination. Draw $c\,b'$ (from the middle of $a\,d$) perpendicular to $a\,c$, and draw the right line $a\,b$ perpendicular to a V. Make $a\,b$ equal to $a\,b'$. Join b V, and a V b is the angle of the oblique face required; consequently, $a\,b$ or $a\,b'$ is the length of the common rafters, and V b is the length of the hip rafters. This comprises the first example.

The second example is the same case of the right trehedral as when there are given the oblique face A V B, and the opposite face C V B of a right trehedral to find the inclination. (13.) This has already been done. The reference now given is sufficient, in order to make the demonstration understood.

† The angles which are already found will give also the bevels of the jack rafters. For the same bevel which is applied to finding the angle which the upper arris and the joint between the back of the purlin and the adjacent face of the adjacent hip rafter make with each other, will give the angle which the longest arris of the back of a jack rafter and the joint of the back of the jack rafter, and the adjacent vertical face of the adjacent hip rafter make with each other, by deducting a right angle from the angle made by the upper arris and the joint of the back of the purlin upon the hip rafter. The other bevels of the jack rafters are the same as the angle which the upper arris of one of the vertical faces of a common rafter makes with the joint between that face and the vertical face of the ridge piece.

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edges of the wall plates, E F the plan of the ridge. From any convenient point E in E F draw E g perpendicular to one of the sides of the planes A D, and in E F make E h equal to the height of the roof, and join $g\,h$. Draw E e perpendicular to A D intersecting A D in g, and make $g\,e$ equal to $g\,h$, and join A e.

Part 2. Draw $e\,f$ parallel to A D, and F f parallel to E e, and join f D. From the point A with the radius A B describe an arc, and from the point e with the radius e A describe another arc intersecting the former arc in the point b'. Join A b' and $e\,b'$. Upon $e\,f$, as a line of symmetry, describe the figure $e\,f\,c\,b$ symmetrical to the figure $e\,f$ D A, and lastly, upon D f describe the triangle D $f\,c'$, so that D c' may be equal to D C and $f\,c'$ equal to f D. Then the several faces of the covering are $e\,f\,c\,b$, $e\,f$ D A, e A b', and f D c'.*

Section IV.

A curved surface is that which, if cut by a plane, the section may be a curve.

A cylindrical surface is a curved surface on which only one right line can be drawn through a given point, and two right lines being drawn through two given points will be parallel.*

Every right line drawn on a cylindrical surface is called a *line of direction*.

If a solid having a cylindrical surface for its superficies be cut by a plane perpendicular to any line of direction, the section of the solid is called a *right section* or *profile*, and every section of the solid which is neither parallel nor perpendicular to a line of direction is called an *oblique* section; moreover, every section of the solid passing along a line of direction is called a *longitudinal* section, and every section which is not a longitudinal section is called a *transverse section*.

Hence every right as well as every oblique section is a *transverse section*.

If the transverse section of a cylindrical surface be one continued curve, the cylindrical surface is said to be *close*; but if the transverse section be open, the cylindrical surface is also said to be *open*.

If an open cylindrical surface terminate in two right lines, the two right lines are called its *rectilinear terminators*.

If the right section or profile of a cylindrical surface be the arc, or the circumference of a circle, the cylindrical surface is called a *cylindric surface*.

If the profile be the curve of an ellipse, the cylindrical surface is called a *cylindroidic surface*.

Of ceilings. A ceiling is that apparent surface of a room which is opposite to the floor, and is of such a nature that a right line which is perpendicular to the horizon can only meet the ceiling in one point.

Cylindrical. A simple *cylindrical* ceiling is that which consists of one cylindrical surface only.

Waggon-headed. A *waggon-headed* ceiling is that which consists of only one cylindrical surface terminating upon the vertical faces of four walls, in such a manner that every right line which is entirely upon the cylindrical surface is comprised between the vertical faces of two opposite walls.

Hence it is evident that in a waggon-headed ceiling, that the concave surface will meet the vertical faces of the other two walls in two right lines, and that the two right lines will be parallel.

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The springing lines of a waggon-headed ceiling are the two right lines in which the cylindrical surface meets the face of two opposite walls.

A plane surface comprised by the two springing lines is called the base of the cylindrical surface.

A close transverse section of a waggon-headed ceiling upon a plane comprised by the curved surface and its base, is called a transverse section of such a ceiling, and the right line which joins each extremity of the curve is called the *base of the section*.

The direction of a cylindric ceiling is the same as that of any of its lines of direction. When a ceiling is formed by two cylindrical surfaces intersecting each other so that a line of direction drawn upon either of the cylindrical surfaces through any point whatever may meet a line of direction upon the other cylindrical surface, such a ceiling is called a *return cylindrical vault*, and each cylindrical surface is called a *branch*.

If a plane be a tangent to the two cylindrical surfaces of a return vault, the two right lines in which the tangent plane touches the two curved surfaces of each cylindrical branch are called the *summit lines*, and the tangent plane is called the *plane of the summit*.

If the rectilinear terminators be both in a plane parallel to the plane of the summit, each of these terminators is called a *springing line*. A groin in a vault or ceiling is the intersection of two concave surfaces, when the angle which they make with each other projects and when the line of common section breaks the continuity of the surface upon either side of it.

A ceiling is called a *rectilinear quadrangular groin* ceiling, when it is compounded only of concave cylindrical surfaces, consisting of four separate branches which have only one common point, and of which two are in one cylindrical surface, and the remaining two in another cylindrical surface, and of which the two branches contained in either of the cylindrical surfaces are entirely on the convex side of the cylindrical surface which contains the other two branches. Rectilinear quadrangular groin.

Hence every rectilinear quadrangular groin ceiling has four groins.

The point in which all the four branches, or in which the four groins meet, is called the *centre of the ceiling*.

If a plane touch the convex superficies of all the cylindrical parts, the plane is said to be a tangent to the surface of such a ceiling, and it will contain the centre of the ceiling.

When the profiles of all the four branches are equal curves, or such as may coincide when their summits and when each branch may be divided by a vertical plane parallel to any line of direction into two symmetrical parts, and when the cylindrical surfaces intersect each other at right angles, the ceiling is called a regular groin.*

* *Observation*. The first part of this process is the same case of the right trehedral as when the two right faces are given, to find the oblique face; (24.) therefore, having found the angle g A e, the angle g D f will be found in the same manner. Fig. 22 is given as an example in which both hips and valleys occur; but as hips and valleys are all described by the same case of the trehedral, a bare inspection of fig. 22 will render the construction sufficiently evident.

* *Illustrations of the preceding Definitions and of the Construction of the Centrings for Groin Ceilings.*

Fig. 1, pl. iv. A perspective view of a groin ceiling, supposed to be executed in masonry. This view exhibits pilasters projecting from the piers between the apertures with circular bows projecting from the cylindrical surface of the ceiling; being supported by the imposts over the pilasters.

Centrings to groin ceilings is the wooden mould upon which the masonry or brickwork is turned; therefore the reverse of the surface

Example. Given the profile W V X, pl. iv. fig. 4, of the cylindric surface of one of the transcripts, to find the profile of the nave and the coverings of the curved surface in plano.

In the curve W V X take any point M and draw M P perpendicular to the ground line fg, meeting the base W X in P. Draw P i perpendicular to W X, meeting the ground line fg in i, and draw ij perpendicular to fg meeting the projection ac of the groin above ac in j. Let wx be the base of the rib of the nave, be perpendicular to the projection of the axis of the cylindrical surface, and draw jp perpendicular to wx meeting wx in p. Draw pm also perpendicular to wx, and make pm equal to P M. Then m and M are corresponding points, and thus to the axis wx the point m is a point in the curve.

In this manner, having found a sufficient number of points, the curve may be drawn through these points, which, being done, is the right section of the nave part of the groin ceiling.

To find in plano the curved surfaces of the two transepts. Let $\gamma\delta$ be the projection of the right section of a profile of the cylindric surface of one of the transepts, and $\alpha\beta$ that of the nave. In the given curve W V X take any point M and draw the line as before, and let ij intersect $\gamma\delta$ in l, also let jp intersect $\alpha\beta$ in k. Extend the curve W V X into the right line qr, No. 3, and in qr, No. 3, let ql and rl be each equal to the arc W M, No. 2. Draw lj, No. 3, perpendicular to qr, and make lj equal to lj, No. 1; and in this manner a sufficient number of points may be found to construct the whole figure $qsutr$, which will be the form of the boarding of one of the transepts in plano.

In like manner $sqrtu$, the boarding of the nave in plano, may be found.

Fig. 5 exhibits the plan and elevation of a groined ceiling to be formed with lath and plaster, the construction of the ribs is found in the same manner as in fig. 4; but here, as well as the right ribs, we shall also require to find the groin ribs. The method for this purpose will be sufficiently evident by merely inspecting the plan in which it is traced upon the diagonal bd, the ordinates being of the same height as in the two profiles. Thus let the semicircle abc be the stretch-out of the groin ceiling, exhibited in the elevation, No. 2, fig. 5. In the semicircular arc abc, pl. v. fig. 1, take a sufficient number of points; but for the purpose it will be sufficient to take these points in the quadrant or half arc; and through these points draw ordinates, and draw gi and df in any convenient situation. Make df and gi respectively equal to bd or ac, pl. iv. fig. 5, No. 1. Then in pl. v. fig. 1, let bj be one of the ordinates of the semicircle meeting the base ac in j, and divide df and gi in p and q, in the same proportion as ac is divided in j. Draw pe and qh respectively perpendicular to df and gi. Make pe and qh each equal to the ordinate jb of the semicircle, and thus the points e and h are in the curves of which the bases are df and gi. The curve being drawn through a sufficient number of points thus found, the curve of the angle rib will be def, and the curve of the ribs of the nave will be ghi. But if the curve of the half of each rib be found, the other being symmetrical will be found in the usual manner. Thus drawing the line cn, take the half of df and the half of gi, and with these distances from the centre o of the semicircle cut the right line cn in n and m. Join rn, rm, and draw lines parallel to cn, which will divide the half bases of the ribs as required.

Example. Given the plans A b N P, O N P Q, pl. iv. fig. 6, of two inclined vaulted passages meeting each other at an angle in a vertical plane; the angles which the springing lines of the arches make with the level plane and a vertical section of the first vault intersecting the springing plane in a line perpendicular to the two springing lines; it is required to construct these vaults with plaster, and to place all the ribs in vertical planes, so that the bases of the common ribs may be perpendicular to the springing lines: the things required to be done by a geometrical construction is to trace the curves on both sides of each half of the angle rib, so that the edge may range in both directions of the vault, as also to trace the curves on each of the faces of the common so as to range in their respective directions.

Let A b and b N, fig. 6, be reciprocally perpendicular to each other. Make the angle N ba equal to the angle of inclination of the springing line of the first direction of the passage, and draw N a perpendicular to b N. Prolong O N to S, and draw N R perpendicular to O S. Make N R equal to N a and make the angle N R S equal to the complement of the angle which the springing line of the second direction of the vault makes with the plan. Prolong T R to meet O N in S, and prolong b A and N P to meet each other in m. Draw N U perpendicular to N P. Make N U equal to N R or N a, and join m U and m S.

We have now given the two right faces, N m S and N m U, of a right trehedral; therefore (17.) (20.) find the inclination mqk, which is the angle made by the plane of the angle rib, and the springing plane of the upper direction of the vault. Draw B C perpendicular to b N.

Let A bnp and $qpno$ (fig. 7) be the springing planes of each direction of the vault, the angles pnb and pno being respectively equal to pnb and $p'n'o'$, (fig. 3.) and b A (fig. 4) equal to b A (fig. 6.) Let b A (fig. 7)

of the groined ceiling which is concave. In practice, the centres are placed first over the widest avenue (or nave) upon a horizontal timber bar at each of the springing lines of the cylindric surface, the two springing lines being upon the level. The two horizontal timber bars are supported by posts, distributed at regular intervals without any regard to the transverse vault, and the centres are placed over the posts, and boarded in without being interrupted by the transepts. Then the groins or intersections of the two cylindric surfaces are drawn upon the boarding over the nave; and the uprights, the beams in the springing, the centres, and the boarding, are all placed on the concave side of the centring of the nave. Fig. 2 is a perspective representation of the centring of a groin vault. This view exhibits the have completely boarded in, with the centres and their necessary supports in the transepts. Fig. 3 exhibits another perspective view which shows both parts boarded in and ready to be built upon.

Fig. 4 is the plan and elevation of a groin ceiling; No. 1 being the plane, and No. 2 the elevation of the transepts. Here the groins are formed by the intersections of a cylindric arch upon the planes of the diagonals. The elevation is here taken upon a plane perpendicular to the axis of the cylinder, fg being the ground line.

The sides of the plan are perpendicular to each other, and the plan and elevation are so placed in respect of each other that right lines drawn from any two corresponding points perpendicular to the ground line will meet the ground line in the same point; and thus all right lines parallel to the axis will be projected in the plan into right lines perpendicular to the ground line, and in the elevation these right lines will be projected into points. It is unnecessary to say more with respect to the orthographical drawings, since those who are familiar with plans and elevations will find the reason and meaning of every line in the construction by merely inspecting the drawings. In the plan, ac and bd are the projections of the groins.

be perpendicular to $n\,b$, and let b A be prolonged from each extremity towards $e\,e$. Through any point e in $e\,e$ draw $e\,d$ perpendicular to $e\,e$, and make the angle $d\,e\,f$, No. 1, equal to the angle $a\,b\,c$. (Fig. 6.) Let the seat $p\,n$ (fig. 7) of the angle rib be prolonged from each of its extremities to $e'\,e'$. Find (26.) the inclination of a plane which shall have a given trace $e''\,e'$, and which shall be parallel to the right line of which the seat is $e\,d$, No. 1, and the angle of projection $g\,e\,f$.

Let $d'\,e'\,f'$, No. 2, be the angle thus found. From the point e', No. 3, draw $e''\,d''$ perpendicular to $e''\,e'$, and make the angle $d''\,e''\,f''$ equal to the angle $m\,l\,k$, fig. 6.

Again, find the inclination of a plane which shall have a given trace $e'''\,e'''$, and which shall be parallel to a right line, of which $d\,e$ is the seat, and $d''\,e''\,f''$ the angle of projection, and let $d'''\,e'''\,f'''$ be the angle thus found.

From any point g' in $e'\,d'$, No. 2, draw $g'\,h'$ parallel to $d\,e$, No. 1; draw $g\,f$ perpendicular to $e'\,d'$ and prolong $d'\,e'$ to i'. Make $e'\,i'$ equal to $e'\,f'$, and join $h'\,i'$. Let the given curve of the rib be A D b. From any point C in the base A b of the given curve of the rib draw C D perpendicular to A b, and draw C E parallel to $b\,n$, meeting $p\,n$ in E. Draw E F parallel to $h\,i$, No. 2, and make E F equal to C D, and F is a point in the curve. In the same manner as many points F, F may be found as will be sufficient to trace the curve. These points being actually found, draw the curve p F n from the one extremity p through the points thus found to the other extremity n.

The curve p Q n is identical to the curve pFn, therefore the ordinates E Q make the same angle with $n\,p$ as the ordinates E F make with $n\,p$; hence all the ordinates E Q are respectively equal to the ordinates E F.

To prevent confusion in describing the ranging curves for the two faces of each half rib, the reader's attention is directed to a separate diagram, No. 5. In No. 5, draw $p\,n$ parallel to $p\,n$, fig. 7, and equal to it, and draw $n\,b$ and p A, No. 5, parallel to $n\,b$ or p A, fig. 7. Then, in No. 5, prolong $p\,n$ to any convenient point e, and draw $e\,d$ perpendicular to $e\,p$. Make the angle $d\,e\,f$ equal to the angle $m\,l\,k$, fig. 6. Again, in No. 5, draw $h\,m$ parallel to $e\,f$, and at such a distance from $e\,f$ as will be equal to the thickness of the half angle rib.

Let $m\,k$, No. 5, meet $d\,e$ in k. In $e\,f$ cut off the part $e\,l$ equal to $e\,k$, and draw $l\,u$ parallel to $b\,n$ or Ap. Draw $l\,v$ and $k\,u$ parallel to $n\,p$, and draw $u\,v$ perpendicular to $l\,v$, and join $t\,v$. Let the curve n F p be identical to the curve nFp, fig. 7, and let F, F, F, &c., No. 5, be any number of points in the curve n F. Draw $n\,r$ and $p\,q$ parallel to $t\,v$ to meet $t\,u$, or $t\,u$ prolonged in q and r, and draw the right lines F G, FG, F G, &c. parallel to $t\,v$. Make F G, F G, FG, each equal to $t\,v$.

A sufficient number of points, F, F, F, &c., being thus found, draw the curve r G q, then r G q will be the higher curve of the intrados of the lower half rib.

The curves n Q p, n F p, fig. 7, being the mitre curves, must necessarily be identical in order to coincide; hence the ranging curve of the upper angle rib will be found in the same manner from the mitre curve, as the mitre curve was found from the ranging curve of the lower half-angle rib; but to remove all doubts from the mind of the reader, we shall also show the manner in which this is to be done.

Draw $k''\,m''$, No. 3, parallel to and at such a distance from $e''\,f''$ as will be equal to the thickness of the half rib, and let $m''\,k''$ meet $e''\,d''$ in k''. From any convenient point w in $p\,n$ draw $w\,u$ parallel to $n\,o$ or $p\,q$, and draw $l''\,v$ and $k''\,u$ parallel to $p\,n$. Draw $u\,v$ perpendicular to $p\,n$, and join $v\,w$. Let Q Q Q be any number of points in the curve n Q p. Draw Q R, Q R, Q R, &c., parallel to $w\,v$, and make Q R, Q R, Q R, &c. each equal to $a\,v$, then r R t is the ranging curve of the upper half rib required.

In order to find the curve of the face and the ranging curves of the ribs in the ascending direction of the vault. It will be necessary to find the projection of one of the ordinates, as X F, upon the springing plane $q\,p\,n\,o$, for this purpose, the trace $e''\,e'$ of the plane of the mitre is given, as also the angle $d''\,e''\,f''$ of projection; this being found, X Z is the projection required; and $g''\,f''$ is the projectant of the projection Z of the point F. Through any convenient point, o in $n\,o$, draw $e'''\,e'''$ perpendicular to $n\,o$, and through any convenient point h''' in $e'''e'''$, No. 4, draw $h'''g'''$ parallel to X Z. Make $h'''g'''$ equal to X Z, and through g''' draw $i'''e'''$ perpendicular to $e'''\,e'''$, meeting $e'''\,e'''$ in the point e'''. Draw $g'''\,f'''$ perpendicular to $e'''\,g'''$, and make $g'''\,f'''$ equal to $g''\,f''$, No. 3. In $e'''\,f'''$ make $e'''\,i'''$ equal to $e'''\,f'''$, and join $h'''\,i'''$. Then, to trace the common rib, draw E S, No. 4, parallel to $n\,o$, meeting $e'''\,e'''$ in S, and draw S V parallel to $h'''\,i'''$. Make S U, fig. 7, equal to any one of the other ordinates, as E F and U thus found is a point in the curve.

In the same manner, having found as many points U, U, U, as may be necessary, draw the curve q U o, fig. 7, which, when done, is the ranging curve of the lower face. Make $e'''\,l'''$ equal to $e'''\,k'''$, and draw $l'''\,j'''$ perpendicular to $e'''\,i'''$, meeting $e'''\,i'''$ in j'''. Draw the ranging lines U V, U V, U V, &c., of the edge of the rib, and make U V, U V, U V, &c., each equal to $k'''\,e'''$, No. 4. Draw the curve x V y, and it will be the ranging curve required.

Fig. 8 exhibits the same plan when the springing planes of the two directions are level; hence in this case all the difficulties of the former disappear since the planes of the faces of all the ribs will be perpendicular to the springing plane, and all the ordinates of the curves perpendicular to their springing lines or bases; moreover, the heights of these ordinates which are in vertical planes, parallel to the axis, will be equal, and the ranging lines of the edges of the ribs will be parallel to the bases of the curves. The whole is so evident from the figure as to render any further explanation unnecessary.

Section V.

One surface is said to fit another, when every point of the first surface coincides with a point in the second.

Any concave surface whatever in a ceiling is called a *cove*. Cove.

When a cove is intended to be formed in a ceiling with plaster upon lath, a receding surface, everywhere equally distant from the apparent surface of the cove to be formed, sufficient to contain the thickness of the lath and plaster together, is called the lathing surface of the cove.

It is evident that if the apparent surface to be formed be a cylindric surface, the lathing surface will also be a cylindric surface; and if the apparent surface to be formed be a spherical surface, the lathing surface will also be a spherical surface: but this will not hold universally.

If a part of a piece of wood be taken away, so that the new surface formed by the part taken away may fit the lathing surface of a cove continued from one extre-

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Rib or Bracket.

mity of the surface to meet the other, such a piece of wood is called a *rib* or *bracket;* and the surface thus fitted is called the *ranging edge* of the rib or bracket. Hence a continued line may be traced on the ranging edge of the bracket from one extremity of the cylindric surface to the other.

If two cylindric surfaces intersecting each other be the lathing surface of two coves, and if the entire intersection coincide in every point with the surface of a piece of wood, and if a portion on each side of this intersection of the superficies of the wood fit each of the lathing surfaces close to the intersection, such a piece of wood is called an *angle rib* or *angle bracket;* and the parts which fit upon the cylindrical surfaces are called the *ranging parts of the surfaces of the angle rib*, or *angle bracket.* A rib or bracket thus fixed is said to be *properly placed.*

In order to form any surface whatever with plaster upon lath, it is evident that every lath must at least be supported in two points; and that the thinner the lath is, the number of points in which it is supported must be more in order to be sufficiently strong to carry the plaster upon which the apparent surface is to be formed.

Hence in forming a coved surface with plaster upon lath, ribs or brackets receding from the lathing surface are generally fixed at such distances from each other, that every lath may be supported upon the ranging edges of the ribs or brackets at three or more points in its length, and that the ribs or brackets thus fixed may have their ranging edges in the lathing surface. When the apparent surfaces of the plaster are required to be formed by two cylindric surfaces intersecting each other, the lathing superficies will also be two cylindrical surfaces intersecting each other. In this case it will be found convenient to fix one extremity of the lath to an angle bracket, and the laths throughout upon a sufficient number of ribs or brackets properly placed. All ribs or brackets, except angle ribs or angle brackets, are called common ribs or common brackets.

In the construction of cylindrical coves in the ceiling of a room to be formed with plaster upon lath, the lath is generally supported upon brackets, and the cylindric surfaces meet each other in such a manner that one of them may terminate upon every vertical plane face of the room, and upon a plane forming the apparent intermediate surface of the ceiling; and that all the terminations of the cylindrical surfaces upon the walls may be in a plane parallel to the plane of the intermediate surface of the ceiling, and that every termination in the ceiling may be parallel to the vertical adjacent surface of the room: such a ceiling constructed with plane and cylindrical surfaces is called a cylindrical, straight, coved, and flat ceiling, or, more generally, such a ceiling is called simply a *coved ceiling*. Hence the plastering of the cove of every straight coved and flat ceiling will require as many angle brackets as the room has plane vertical faces.

In order to save timber, every rib or bracket in the construction of a cylindric surface ought to have two surfaces in parallel planes, which may always be perpendicular to every line of direction of the lathing cylindrical surface. These parallel plane surfaces are called the planes of the brackets. Hence when a cylindrical cove to be formed with plaster upon lath is required to be constructed, and to have any line of direction parallel to the horizon, if the brackets are fixed so that their surfaces may be perpendicular to the horizon, the ranging edges of the brackets will be perpendicular to the planes of these brackets; but, whatever be the position of a line of direction, the planes of every two brackets which range in a cylindrical surface are generally perpendicular to the horizon, and parallel to the plane vertical surface of the wall; and thus, when a line of direction of the cylindrical surface in which the ranging edges of the brackets are placed is not parallel to the horizon, this line of direction will not be perpendicular to the planes of the brackets.

Brackets to form small cylindrical coves with plaster, seldom require more timber than can be obtained from a board in one single piece; but ribs to support lath and plaster, as well as the brackets of large cylindrical coves, require that each rib or bracket may be formed in two or more pieces of boards joined together, so as to form a whole bracket in two thicknesses; and that the joint between the two halves may be in a plane parallel to the planes of the rib, and equidistant from these planes. When two cylindrical surfaces intersect and form a plane curve, it will be convenient to make the angle rib or angle bracket, if large, in two thicknesses, so that the joint between them may be in a plane parallel to the planes of the angle rib or angle bracket.

The cylindrical surfaces which are generally used in coved ceilings, intersect each other in a plane curve, and the plane of this curve is generally perpendicular to the horizon. Moreover, two right sections of the two cylindrical surfaces are generally such that the two curves will reciprocally coincide in all parts. In this general case it will be found convenient to form angle ribs or brackets in two thicknesses of boards, and the joint or plane of coincidence to be in a plane of the curve in which the two cylindrical surfaces meet each other. It is evident that all the parallel plane surfaces which comprise the brackets are sections of the cylindrical surface in which they may be arranged, and when two faces of every two brackets are parallel to one another, as in common brackets, and their ranging edges in the same cylindrical surface, that the sections of these brackets, by the cylindrical surface, are identical curves; and that the curve lines of all the parallel ribs or brackets are identical curves. Moreover, as cylindrical surfaces are generally so situated in coved ceilings that their lines of direction are parallel to the horizon; and as all the ribs or brackets are generally, and most conveniently arranged in parallel planes, these planes will be all perpendicular to the lines of direction of the cylindrical surface into which their edges are arranged; hence all the ranging edges of these brackets will be perpendicular to their vertical faces; so that, if a right section of the cylindrical surface is obtained, and a mould be made so as to contain this section, this mould will serve to draw the curves on one of the faces of every common bracket; and these being properly fixed with angle brackets when necessary, will be in the lathing surface required.*

* The cylindrical surfaces commonly employed are those of cylinders, or those which have their right sections greater or less portions of the circumference of a circle. Sometimes, however, various other curved surfaces may be used with good effect. Of these the cylindrical surfaces generally employed are those of cylindroids; and the curves of the right sections of cylindroidal surfaces are, generally, either quadrantal portions between the two axes, of which one is horizontal and the other vertical.

Every cylindrical surface used in coving will be sufficiently determined by having given a right section of the cylindrical surface. Moreover, two cylindrical surfaces intersecting each other will be

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To find the ranging edge, we have only to cut through the thickness of every such board perpendicular to the two plane faces by taking away the part on the concave side of every rib or bracket, in order to form the ranging edges required.

Examples to the preceding Observations in ranging the Ribs of Groin and Cove Ceilings.

Example 1. Let pl. v. fig. 2 be the plan of a portion of a coved surface at an internal angle, *a e* and *a m* the springing lines, *b n* and *b f* the ceiling line in each return. The angle bracket is traced in the same manner as the angle rib of a groin: *a b d c* is the plan of half the angle rib, *a b* the base of the mitre curve, and *b h* perpendicular to *a b* the height, the curve itself being *a h*.

Draw the chord *a h* of the curve, and draw *c k* perpendicular to *a b*, meeting *a b* in *k*, and draw *k l* perpendicular to *a h*, meeting *a h* in *l*.

Let *a e f b*, No. 1, be the edge of a board, out of which a bracket is to be formed, *a b c d* and *e f g h* the two faces of the board which comprise the edge *a e f b* between them. Draw the right line *o q* perpendicular to *a b* or *e f*, intersecting *a b* in *p*, and *e f* in *q*, and make *p o* equal to *l k*, fig. 2. In No. 1 and in No. 2 through *o* draw *i n* parallel to *a b*, and in *i n* make *o n* equal to *a l*, fig. 2. Apply the mould *a h*, fig. 2, to No. 1 and No. 2, so that the extreme points *a* and *h* of the curve, fig. 2, may be in the arris line, *e f*, No. 1 and No. 2, *viz.* the point *a*, fig. 2, upon the point *q*, No. 1 and No. 2, and the point *h*, fig. 2, upon the point *l*, No. 1. Then, upon the face *e f g h* draw the curve *q r l*. Remove the mould from the face *e f g h*, and place it upon the other face, *a b c d*, so that the points upon *q* and *l* may be in *n i*; *viz.* *q* upon *n*, and *l* upon *m*. Then, upon the face *a b c d* draw the curve *n s m*. The two curves *n s m* and *q r l* are the curves in the parallel faces of the brackets; then the wood on the concave side being cut away will give the ranging required. No. 1 and No. 2 being put together as they ought to be, will complete the angle bracket for its situation.

Example 2. Let pl. v. fig. 3 be the plan of a portion of the curved surface at the external angle, *o y* and *o t* the springing lines, *p s* and *p z* the ceiling lines in each return. The angle bracket being traced as before, *o p r q* is half the plan of the angle rib, *o p* the base of the mitre curve, and *p x* perpendicular to *o p* the height, the curve itself being *o x*.

Draw the chord *o x* of the curve, and draw *q u*, meeting *p o* prolonged in *u*. Draw *u v* parallel to *o x*, and draw *o w* perpendicular to *u v*, meeting *u v* in *w*. Let *a e f b*, No. 3 and No. 4, be the edge of a board, out of which a bracket is to be formed; and let *a b c d*, *e f g h*, be the two faces of the board which comprise the edge *a e f b* between them. Draw the right line *i l* perpendicular to *a b* or *e f*, intersecting *a b* in *l*, and *e f* in *k*; and make *k i* equal to *o w*, fig. 3. In No. 3 and No. 4 draw *i n* parallel to *a b*, and in *i n* make *i m* equal to *o u*, fig. 3.

Apply the mould *o x*, fig. 3, to No. 3 and No. 4, so that the extreme points *o* and *x* of the curve, fig. 3, may be in the arris line *a b*, No. 3 and No. 4; *viz.* the point *o*, fig. 3, upon the point *q*, No. 3 and No. 4; and the point *x*, fig. 3, upon *l* in No 3 and No. 4. Then upon the face *a b c d*, in No. 3 and in No. 4, draw the curve *l r q*. Remove the mould from the face *a b c d*, and place it upon the other face *e f g h*, so that the point upon *q* and *l* may be in *ni*; *viz.* the point *q* upon *n*, and *l* upon *m*; then upon the face *e f g h* draw the curve *m s n*. The two curves *n s m* and *q r l* are the curves in the parallel faces of the bracket. Then the wood on the concave side being cut away so as to form the cylindrical surface, will give the ranging required.

Example 3. Fig. 4 is the plan of an equilateral and equiangular cylindric groin ceiling, the ribs across the diagonals are in half ribs, and every half rib is the same as an angle bracket upon an external angle. In this Example the arches are semicircular, and of the same radius as the quadrantal circular arcs, fig. 2 and 3, of the common brackets, and therefore the mould for each half angle rib of the groin ceiling is the same as is found for the angle ribs, Examples 1 and 2; and, as the angles of the groin are all external, the ranging of each of the ribs will be found in the same manner as the angle bracket, fig. 3; and this will be evident by again reading the description to the second Example to the groin ceiling, fig. 4, where the same letters of reference are applied as in fig. 3.

Example 4. Fig. 5 exhibits the plan of an oblong cylindric groin; No. 9 exhibits the face mould; No. 6 and No. 7 the application of the face mould to the ranging of one of the half ribs; No. 8 and No. 9 the application of the face mould to another of the half ribs which form an acute angle with the former.

Fig. 6 exhibits an application of the same principles to the backing of common or hip rafters.[*]

SECTION VI.

Cylindro cylindric ceilings.

A proper *cylindro cylindric ceiling* is a ceiling, or part of a ceiling, formed by two cylindric surfaces intersecting each other in such a manner that they may have four branches; and that no part of either of the cylindric surfaces may be comprised within the concave surface of the other; and that all the springing lines of the two cylindric surfaces and the axis may be in one horizontal plane, and that the two cylindric surfaces may not have a common tangent plane.

A proper cylindro cylindric ceiling is given when the plan of the springing lines are given in a plane parallel to the plane which contains them; and when the right sections of the portions of the cylindric surfaces terminated by the springing lines are given.

Example. Let *a l* and *s v*, pl. v. fig. 7, be the two springing lines for one of the cylindric surfaces, and *c u*, *c t*, the two springing lines for the other cylindric surface; and let *c d e* be the section of the cylindric surface, of which the springing lines are *c u* and *c t*; and let *a q s* be the section of the cylindric surface, of which the springing lines are *c l* and *s v*; and let *c e* be the base of the curve *c d e*, and *a s* the base of the curve *a q s*. Moreover, let *a l* intersect *c t*, and *c u* in *b* and *f*; then *b* and *f* are the plans of the springing points of the

given when the right sections of these are given, and when the angle which two lines of direction make with each other are given; but these will not be sufficient to fix ribs or brackets in their situations with regard to the vertical faces of the rooms and the plane in the intermediate part of the ceiling. In this case we must have given, besides a right section of the cylindrical surface, a plan and elevation of the springing and ceiling lines of each of the two cylindrical surfaces.

The same principles extend to the construction of lathing surfaces, whether they may be coves in ceilings or otherwise.

intersection upon one side. It is now required to find the projection of the two cylindric surfaces.

In the curve *c d e* take any point *d*, and draw *d m* perpendicular to *c e*, meeting *c e* in *m*. Draw *m n* parallel to *c t* or *e u*; and from the point *o* in *a s* draw *o p* perpendicular to *a s*. Make *o p* equal to *m d*, and draw *p q* parallel to *a s*, meeting the arc *a q s* in *q*. Draw *q r* perpendicular to *a s* meeting *a s* in *r*, and draw *r n* parallel to *a t* or *s v*. Then the point *n* is the projection of an intermediate point in the curve of which *b* and *f* are the projections of the springing points. In this manner may be found as many points as will be necessary to trace the curve *b x f*, which is the plan of the intersection required; and in this manner the plan *t y u* of the opposite intersection will be found.

The plans of the two intersections are thus found by projection; but, as it is known that the projection of two cylindric surfaces are hyperbolas when the right sections of both cylindrical surfaces are circular arcs of different radii, and when the projection is made upon a plane which contains the two axes of the cylindrical surfaces, the intersections may therefore be found independent of the principles of projection. We shall here show by an example how this is to be done.

Let the semicircles *a b c*, *d e f*, fig. 8 and 9, be the right sections of the cylindric surfaces, *a c* and *d f* being the diameters of these semicircles placed upon the same right lines having the same centre, and let *g i* and *h j* be the springing lines of the cylindric surface which has the greatest diameter, and let the springing lines be parallel to *d f*.

Draw *e m* and *a n* perpendicular to *g i* or *h j*, intersecting *g i* in *k* and *l*, and *h j* in *m* and *n*; and draw *b e* parallel to *a c*, and a tangent to the semicircle *a b c*, to meet the semicircle *d e f* in *e*. Draw *e u* perpendicular to *d f*, meeting *d f* in *u*, and bisect *k l* in *s*. Draw *s t* perpendicular to *k l* intersecting *m n* in *t*, and in *s t* make *s o* and *t p* each equal to *f u*; then, having the vertices *o* and *p* of the two opposite curves of an hyperbola, describe the curves *k o l* and *m p n*; and these will be the projections of the two intersections required.

Fig. 8 is adapted to the same plan as fig. 7. In fig. 9 the two cylindric surfaces are nearly equal; that is, their diameters are nearly equal to one another. The manner of drawing the two hyperbolic opposite curves as shown by dividing each ordinate into the same number of equal parts, and dividing the ends of the rectangle into the same number of equal parts; then, drawing right lines from the opposite vertices to these points, to intersect as in the figures.*

Example. Given the projections of the springing lines, the heights of the cylindrical surfaces, and the height of the spheroidal surface above the springing plane, which is parallel to the plane of projection, to find the projections of the intersections of the curved surfaces.

Let fig. 10, No. 2, be the elevation, and let No. 1 be the plan. In No. 1 let A P E Q be the springing line of the spheroid, and let *t u* and *t' u'* be the springing lines of one of the cylindric surfaces, *x y*, *x' y'* the springing lines of the opposite cylindric surfaces; also let *v w*, *v' w'* be the springing lines of the passages in the transverse direction; and let *r s*, *r' s'* be the springing lines of the opposite end of the transverse direction. In the construction of the hyperbolas, which are the projections of the intersections of the curved surfaces of the cylindric surfaces, are given the double ordinates K K', I I', L L', and N N', and the axis B D and X Z, to describe the hyperbolas, which being done, let the curves be K' B K, G H I, L' D L, and Y Z M, which will be the projections of the intersections of the curved surfaces required in the horizontal plane.

The parts *u* K N' *v'*, *r* N L *x*, *x'* L' I' *r*, and *r'* I K' *u* of the plan are pilasters placed under the springings between the intersections of the curved surfaces.

In the elevation No. 2, let $\beta\gamma$ be the ground line, and let it be perpendicular to P Q, and hence parallel to A E, then the right sections of all the cylindric surfaces being semicircles, the cylindric surfaces of which their axes are perpendicular to the elevation will be projected into semicircles, of which their diameter will be parallel to the ground line. Let this projection be made, and let it be *g h i*, No. 2, and let *f h* be the radius perpendicular to the terminating diameter *g i*. Prolong *g i* to *a* and *e*, and make *f e* and *f a* each equal to C A or C E, No. 1, the radius of the circle of the spheroid contained in the springing plane. Through *h* draw *n p*, No. 2, parallel to *a e*, and draw B *b*, D *d* perpendicular to the ground line $\beta\gamma$ to meet *n p*, No. 2, in *b* and *d*. Draw C *c* perpendicular to the ground line $\beta\gamma$, and from either of these points *b* or *d*, as *d* with a radius equal to *f a* or *f e*, cut C *c* in *g*. Draw *g d* intersecting *a e* in *r*, and make *f c* equal to *r d*. Then by means of the axis major *a e*, and the semiaxis minor *f c*, describe the semiellipse *a b c d e*, and *a b c d e* is the section of the spheroid required; from this the ribs of the ceiling may be constructed. The lines *k b* and *l d* are the projections of the two intersections of the curved surfaces, of which their projections are the hyperbolic curves K' B K, L' D L.

Section VII.

A *pendentive* ceiling is a ceiling consisting of the portion of a spherical or of a spheroidal surface, comprised by the vertical faces of the walls of a room. Pendentive ceilings.

A proper *spherical* or *spheroidal*, *pendentive* ceiling is a ceiling comprised by the vertical faces of the four walls of a room rising from a rectangular plan, so that the intersection of the vertical diagonal planes of the room may pass through the centre of the spherical or spheroidal surface.

A *regular*, *polygonal*, *spheroidal*, *pendentive* ceiling is a spheroidal surface comprised by the vertical planes containing the inner faces of three or more adjacent walls, rising from a plane which is a regular polygon in such a manner that the axis of rotation of the spheroidal surface, being prolonged, may pass through the centre of the polygonal plan.

A *proper*, *quadrangular*, *spheroidal*, *pendentive* ceiling is the portion of a spheroidal surface comprised by the vertical planes which contain the four inner faces

* If two equal semicylindric surfaces intersect a spheroidal surface, so that the axis of the semicylindric surfaces may intersect each other at right angles in the centre of the spheroidal surface: and that the springing lines of the two cylindric surfaces, and the springing line of the spheroidal surface, and the two axes of the cylindrical surfaces may be all in the same plane; and that the springing line of the spheroidal surface may be the circumference of a circle, of which the diameter is greater than that of either of the cylindrical surfaces, and that no part of any of the cylindrical surfaces may be within the concave side of the spheroidal surface; such a ceiling is called a proper *spheroido cylindric ceiling*.

The projections of the four curves upon the springing plane, of the four intersections of the cylindric surfaces, and the spheroidal surface, are hyperbolas, having their axes terminated by the vertices of the curves in each pair of opposite projections.

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of a room, of which the plan is a rectangle, and of which the vertical, diagonal planes intersect each other in a right line containing the axis of rotation of the spheroidal surface.

Springing curve.

The intersection of a spherical or spheroidal surface and the plane of every wall of the room, is called a *springing curve.**

In the construction of pendentive ceilings it will be convenient to place all the ribs in vertical planes passing through the centre of the sphere or spheroid; for in this position of fixing the ribs all the ribs may be formed by means of one mould only; since in this position they will all have the same curvature and will all intersect in one point of the spheric surface. In order to divide the ribs equally, it will also be convenient that the vertical planes which contain the curves of the ribs may make equal angles with one another, and that four of these ribs may be in the two diagonal planes. We shall call the ribs placed in these planes the diagonal ribs; hence if one of the diagonal ribs be found, every radial rib will be less than a diagonal rib.

Example. Let it be required to construct a spherical pendentive ceiling over a given square plan A B C D, pl. vi. fig. 2.

Then, because the chords of the springing curves are equal to the sides of the plan, and since in this example the sides of the plan are all equal, the chords of the springing curves to any side of the plan are equal.

Draw the diagonal A C, then A C will be equal to the chord of the diagonal ribs. Upon A C as a chord describe the arc A $e f$ C of a circle, and the perpendicular $g h$ from the middle of the chord is equal to the perpendicular from the middle of the chord of each of the springing curves. Therefore bisect the chord C D of the springing curve upon C D, and draw $i l$ perpendicular to C D. Make $i l$ equal to $g h$; and from the point l, with a radius equal to l D or l C, describe the arc C k D, which will not only be the springing curve for the face of the room of which the plan is C D, but also for every other face.

Now since all the radial ribs are of the same curvature and their lengths only differ, and since the curve of a diagonal rib is given, we have only to cut an arc from the curve of the diagonal so as to stand over the plan required. Thus let r be the middle of the curve A $e f$ C, and let $m n$ be the plan of one of the ribs; also let $g m$ be the radius of the horizontal circle upon which this rib is intended to terminate upon. With the radius $g m$ describe the semicircle $d m t$, meeting A C in d and t, and draw $d e$ and $t f$ each perpendicular to A C, meeting the curve A $e f$ C in e and f; then A e or C f are the portions of the curve for each diagonal rib, in order either to be terminated by a horizontal cornice or by a conic skylight in the middle of the ceiling. Again from the centre g with the distance $g n$, the length of the plan of a rib, describe the arc $n p$, meeting the diagonal A C in p, and draw $p q$ perpendicular to A C, meeting the curve A $e f$ C in q; then $q e$ is the portion of the curve of the edge of the rib which will stand over $m n$ in the plan.

Section VIII.

Niche.

A *niche* is a recess in a wall generally formed by a cylindric surface standing upon a level surface and surmounted by a spheric surface, so that the axis of the cylindric surface may be vertical and may pass through the centre of the spheric surface, and that cylindric and spherical surfaces may meet each other in a horizontal plane, and that the cylindric and spherical surfaces may have the same tangent plane, and that the cylindric and spherical surfaces may be terminated each by the vertical surface of the wall.*

Example. In fig. 3, let m, No. 1, be the projection of the line in which the vertical planes of the ribs which pass through the centre intersect $a m$, the plan of the wall, $a d g m$ the projection of the springing horizontal arc. Let this plan be divided into ribs, and let the two faces of one of these ribs be represented by the right lines $e n$ and $f p$. Let the outer circle, in which the back of these ribs may be supposed to be placed, be $l p i$. From the points e and f, in which $e n$ and $f h$ meet the inside of the front rib, draw $e i$ and $f h$ perpendicular to $e n$, and let these lines meet the inner curve in g and b'; then $g b i h$ shows the joint at the top; $g h$ and $b i$ being the right lines in which this joint terminates upon each face of the rib. Of this rib $d b$ is the length of the curve on the inside over $e d$, and $d g$ is the length of the curve over $f o$. In this construction, as the bisecting planes of the ribs all meet in a vertical axis, the projection of this axis is the point f, which is the centre of the projections of all the ribs. The construction of the remaining rib will be found in the same manner as the rib now described. No. 2 is the elevation to the plan No. 1.

Again, because the top or head of the niche is a portion of a hemisphere of which the springing plane is

* The extremities of all the springing curves are in a plane parallel to the horizon, and when the surface of the ceiling is spherical, and when the plane containing the extremities of the springing curves passes through the centre of the sphere, the springing curves will be all semicircles.

If the plane containing the extremities of the springing curves be above the centre of the sphere, then the centres of the springing curves will be at the same distance below their chords, as the centre of the spheric surface is below the horizontal plane which contains the extremities of the springing curves.

Moreover, when the surface of a ceiling is spheroidal, and when the horizontal plane containing the extremities of the springing curves passes through the centre of the spheroid, and when the axis of rotation is in a vertical position, the springing curves in the planes which contain the inner faces of the walls of the room are all similar to the curve of the vertical section of the spheroidal surface passing through the centre.

A room having a regular or proper pendentive ceiling will admit of the most elegant decorations of pilasters and columns, as appears from the perspective view, pl. vi. fig. 1, where A is one of the four spherical pendentives which is formed by a horizontal cornice at the top, and the two architraves bordering upon the springing curves in the planes of two adjacent walls.

* In the construction of the head of a spherical niche, since the lathing surface of a spherical niche is spherical, as well as the apparent surface of the head, the curves of the ribs will be portions of the circumference of a circle; and if the curves of the ribs be in planes passing through the centre of the sphere, all the edges of the ribs which are in these planes will have equal curvatures, and, consequently, will have equal radii; moreover, if the ribs be in vertical planes which pass through the centre of the sphere, the planes of all the ribs will be perpendicular to the horizontal plane in which the cylindric and spherical surfaces terminate. If the surface of the wall be a plane surface, and if it contain the axis of the cylindric surface, the curves of all the ribs will be quadrants of circles which will all have the same radius; but if the axis of the cylindric surface be without the face of the wall, the curves of the ribs will be arcs of circles of the same radii, and these curves will be each less than a quadrant.

In the plan, the springing between the cylindric and spheric surfaces will be projected into the arc of a circle, and all the ribs which are in vertical planes will be projected into right lines, and the vertical line in which the back ribs intersect will be projected into a point which will be a common termination for all the back ribs.

the base, all sections of the hemisphere perpendicular to this base will be semicircles; or because the springing plane passes through the centre of the sphere, all the sections of the spherical surface perpendicular to the springing plane will be semicircles; hence the front rib of the niche will be a semicircle for the plane if the wall is perpendicular to the springing plane.

JOINERY.

Joinery is the art of fixing various pieces of wood together, chiefly for such parts of the interior of a building as are exposed to the eye, and which are employed in the construction of doors and windows, and for forming the various margins round plaster in order to cover all external angles, and thereby protect it in its weakest parts from injury or accidental violence, so as to render these parts comfortable, convenient, and agreeable to the eye.

Joinery may be extended to various decorations both exteriorly and interiorly, as in architraves, bases, surbases, pilasters, columns, &c., as also in the linings of walls, or partitions, in the forms of boarding and wainscoting, and in the construction of stairs and hand rails.

For all these purposes the surfaces which are exposed to the eye ought to be made quite smooth, and the joints between every two separate pieces of wood perfectly close.*

Section I.

The best stairs are constructed with an opening in the middle of the stair formed by the ends of the steps, which are generally all in one surface, rising perpendicularly to the horizon from a given line on the floor, which line is called the *plan of the ends* of the steps, and the open space in the middle of the staircase is called the *well hole*.

The *hand rail* is a fence made adjacent to the well hole, raised to such a height above the steps and supported by vertical bars called *balusters*, as to prevent those who ascend or descend from falling through the well hole. In the formation of the straight parts the workman requires no directions: we shall therefore treat only of the construction of the curved parts, or of the curved part of a rail, and so much of the straight parts as not only give the proper direction or position, but also afford the best means of fixing the straight and circular parts together.

A body is said to stand over a given plan when a right line drawn from any point whatever in the outline of the plan perpendicular to the horizontal plane, can only touch the body thus raised.

A stair is said to make as many revolutions as the stories are in number through which the stair is carried, and all these revolutions generally stand over the same plan.

The hand rail is generally prepared in such a manner that the section of the rail made by a vertical plane drawn perpendicular to any tangent whatever, to the convex or concave side of the plan through the point of contact, may be a rectangle, and that the rectangle may have two sides perpendicular, and consequently two sides parallel to the horizon; moreover, that every two of those rectangular sections may have the same horizontal breadth. The figure of the rail having this property is said to be *squared*. A rail thus squared will have four visible sides or faces, of which two are cylindrical and stand immediately over the sides of the plan, and of which the other two are spiral surfaces, and cover the area of the plan between its outlines. The convex cylindrical surface when extended in plano ought to be everywhere of equal breadth.

The figure of the convex surface extended in plano is called *a falling mould*.

As the curved part of a squared rail is generally put together in two parts, so as to form the entire curved part, with the addition of a small part of the straight rail joining each extremity of the curved part, each part may be comprised between two parallel planes, of which one may be made to touch one of the spiral surfaces in three points, and the other to touch the other spiral surface at least in one point.

Then it is evident that the whole rail may be contained between two cylindrical surfaces and two parallel plane surfaces. Therefore the sections of the cylindrical surfaces in these parallel planes will be equal; and since the outlines of the plan of the rail are right sections of the cylindrical surfaces, we have only to find from the right section an oblique section of the two cylindrical surfaces in the same position as the two parallel planes would be when the rail is put in its proper position. A mould formed to such a section is called a *face mould*.*

Example. In a semicylindric stair terminating with parallel straight walls, let $a\,b\,c\,d\,e\,f\,c, \ldots a$, fig. 5, be the plan, the half of the rail over the circular part; the quadrant $b\,c\,d\,e\,f$ being half the ground line of the semicylindric surface which contains the convex side of

* In the operations of Joinery, the field of application of those extensive principles, to which the Art of Carpentry has been so much indebted, is narrow and not so generally interesting. We cannot, however, dismiss this subject without laying before our readers some of their further applications, and such as will be both advantageous and agreeable to the pursuits of the ardent student in the general knowledge of construction.

Among these the principles and construction of hand rails will be found of the greatest utility; we shall therefore invite the reader to direct his attention to that subject.

* Hence, if the piece of wood out of which a part of the rail is to be made, has its thickness equal to distance between the parallel planes, the rail may be cut out of the wood by applying the face mould on each side of the plank in its proper position; and having cut away the superfluous wood, so as to form the concave and convex cylindrical surfaces, it will only remain to apply the falling mould in its proper position, and then to form the spiral surfaces by means of the lines drawn upon the cylindric surface, from the falling mould, and the part of the rail thus squared, when set up in its situation, will arrange over its plan as required. All that is then required is to find the face mould and the falling mould.

The position of the plane of section may be determined by having given three points on the plan, and the perpendicular heights of the right lines standing upon these points to the under spiral surface of the rail.

From what has now been explained, it is expected that the reader will have his ideas sufficiently clear to comprehend the construction of hand railing.

The plan of a hand rail must be regulated by the plan of the stairs. The most general form of a staircase is that of which the vertical superficies of the walls is a semicylindric surface, joined at each edge by two plane surfaces, which if prolonged would be tangents to the semicylindric surface, and are consequently parallel to one another; the staircase is enclosed by a third wall, of which the inner vertical surface is perpendicular to the other two vertical surfaces which join the semicylindric surface. So that the plan of such a stair is in the form of the letter D. Fig. 4, plate vi. exhibits the two projections of a staircase and stair as that now described. The faces of the steps are all perpendicular to the interior vertical surface of the surrounding wall, therefore in the straight walls they are in parallel planes, and in the circular part they bend to the axis of the cylindric surface. Those steps in the cylindric part are called winders, and those in the straight part are called fliers.

the rail, and the quadrant $\beta\gamma\delta\epsilon$, the ground line of the semicylindric surface, which contains the concave vertical surface of the rail, the right lines $a\,b$, $a\,\beta$, the groined lines of the planes containing the exterior and interior surfaces of the straight parts of the rail, and the right lines $a\,\alpha$, $f\,\epsilon$, the ground lines of the vertical planes which contain the joints. Moreover, let a, b, ϵ be the ground points of three vertical right lines which contain the heights of the rail or distances from the plan to the under spiral surface; besides this are given the heights above these points to the under spiral surface of the rail to find the falling mould, and the face mould, as also to show the positions in which these moulds may be applied to the plank.

In fig. 6, draw the right line A D, and in A D make A B equal to the breadth of one of the steps in the fliers. Draw B C perpendicular to A D, and make B C equal to the height of one of the steps. Join A C, and make B F equal to $b\,a$, fig. 5. In the right line A D, fig. 6, make B D equal to the length of the circular arc $b\,c\,d\,e\,f$, fig. 5, and draw D K perpendicular to D A. In D K make D E equal to the height of as many steps, and one more than the half of the circular part of the plan contains winders, and join E C. Cut off the angle at C by the curve G H K, so that C A and C E may be tangents to the curve at G and K.

The A G H K E is the under side of the falling mould. Draw the mixed line I J K equidistant from a mixed or compound line A H E, so that the distance between the two compound lines may be everywhere equal to the breadth of the developement of the convex cylindric surface of the rail, and these lines will form the falling mould required. Prolong B C to meet the under edge of the falling mould in H; and F G, B H, and D E are the three heights of the rail over the points a b, ϵ, fig. 5.

It now remains to find the oblique section of the cylindric surface by a plane passing through the three points of which a, b, ϵ are the feet. Join $\epsilon\,a$, fig. 5, and draw $b\,z$ parallel to $\epsilon\,a$. Draw the three right lines $a\,n$, $b\,x$, and $\epsilon\,y$ perpendicular to $\epsilon\,a$, or at any given angle with $\epsilon\,a$, so as to be parallel with each other, and make the right lines $a\,n$, $b\,x$, and $\epsilon\,y$, respectively equal to F G, B H, and D E, fig. 6; but as the object is to obtain the intersection of the plane, which contains the section to be found, this object will be found more conveniently by making $a\,n$, $b\,x$, and $\epsilon\,y$ a certain part of each line. Let therefore $a\,n$, $b\,x$, and $\epsilon\,y$ be each respectively equal to one-third part of F G, B H, and D E, fig. 6. In fig. 5 join $y\,n$, and draw $x\,z$ parallel to $y\,n$. Prolong $\epsilon\,a$ and $y\,n$ to meet each other in o, and through the points o and z draw the right line T U, which is the intersection of the plane which contains the section of the rail to be found. Through any convenient point T in T U draw the right line T V perpendicular to T U, and draw $\epsilon\,l$ perpendicular to T V, meeting T V in l. Draw $l\,l'$ perpendicular to T V, and make $l\,l'$ equal to D E, fig. 6, and in fig. 5 join E l', which prolong to W if necessary.

Then $a\,b\,c\,d\,e\,f$ may be considered as the base or right section of a cylindrical surface, T U the intersection of a plane cutting that cylindrical surface, and V T W the angle of inclination of that plane; it is required to find the sections of the cylindric surface upon this plane. This section will be found in the very same manner as that of an angle bracket, or angle rib of a cove ceiling, and the application of the moulds to the plank will be found in the very same manner as the application of the moulds to the boards in forming an angle bracket.

Thus let the oblique sections of both cylindrical surfaces be found, and let them be $a'\,b'\,c'\,d'\,e'\,f'$ and $a'\,\beta'\,\gamma'\,\delta'\,\epsilon'$. Join $a'\,\epsilon'$, and draw $p\,q$ parallel to T V, and at such a distance from T V as may be equal to the thickness of a plank sufficient to contain the rail, and let $p\,q$ meet $l\,l'$ in q. Draw $q\,r$ perpendicular to T W, and draw $\epsilon'\,r$ parallel to T W, also draw $r\,s$ perpendicular to $a'\,\epsilon'$ meeting $a'\,\epsilon'$ in s.

In fig. 7, plate vi., let L M O N be the edge of the plank, L P Q M the top, N R S O the under face. We shall call $a'\,b'\,c'\,d'\,e'\,f'\,\epsilon' \ldots a$, in fig. 5, the face mould. Apply the face mould in fig. 5 to the face P L M Q, fig. 6, of the plank, so that the points $a'\,\epsilon'$, fig. 5, may be upon L M, fig. 7, *viz*, ϵ upon t, and a, fig. 5, upon z, fig. 7, and draw Y the figure of the mould. In L M, fig. 7, make $t\,u$ equal to $\epsilon'\,s$, fig. 5, and in fig. 7 draw $u\,w$ perpendicular to L M, intersecting N O in v. Make $v\,w$ equal to $r\,s$, fig. 5, and draw $u\,x$ parallel to N O. Apply now the face mould so that the points ϵ', a', fig. 5, may be in the line $w\,x$, fig. 7, the point ϵ' being upon w, and the point a' upon x, and that the entire mould may be upon the face N O S R. Then the figure of the mould being drawn also upon this side of the plank, the two figures thus drawn will be true sections of the cylindrical surfaces required, and if the plank containing these figures be set up in its real position, the curve line $a'\,b'\,c'\,d'\,e'\,f'$, fig. 5, will fall over the ground line $a\,b\,c\,d\,e\,f$, and the curve line $a'\,\beta'\,\gamma'\,\delta'\,\epsilon'$ will fall over the curve line $a\,\beta\,\gamma\,\delta\,\epsilon$.

Having cut away the superfluous wood on the outside of the figures, the two helical surfaces may be formed by means of the falling mould, and what remains to be done will be understood by the workman.

The mitre cap of a rail is a piece of wood formed into a surface of revolution, in order to terminate a straight hand rail, and is generally employed when the stair has no well hole.*

In fig. 8 assume the point s' for the projection of the axis of rotation, and from s' with a radius equal to the radius of the great circle of the mitre cap describe the circumference $a'\,g'\,f'$ of a circle, and this circle will be the projection of the contour of the mitre cap. Draw $s'\,s$ in any convenient direction for the projection of the

* The rail is mitred into the circular cap, which is of greater diameter than the breadth of the straight rail, and the two are joined together in such a manner, that, when finished, a vertical section may divide both the rail and the mitre cap into two symmetrical parts; and that this plane may pass through the axis of revolution of the mitre cap, and longitudinally along the rail; and that the back of the rail, after descending in a right line, may proceed in a curve until it becomes level, or has a horizontal tangent at the point where it meets the circular cap; and that the surface of the rail and the surface of revolution of the circular cap may meet each other in two vertical planes only; and that the intersection of the meeting planes may be in the longitudinal plane which divides the hand rail and the mitre cap each into two symmetrical parts.

Let the plan of the rail and the mitre cap be so projected that the axis of rotation of the mitre cap may be perpendicular to the plane of projection; then the plane which divides the part of the rail and the mitre cap each into two symmetrical parts will be projected into a right line, and the centre of the mitre cap will be projected into a point, and the contour of the mitre cap will be projected into a circle of which the diameter is equal to the great circle of the mitre cap. The point which is the projection of the axis of rotation will be the centre of the circle, which is the projection of the contour of the mitre cap, and the right lines which are the projection of the planes containing the mitre will be radii of the circle, provided these planes pass through the axis of rotation as they are supposed to do.

vertical plane which divides the rail and the mitre cap into two equal parts. Then the projections of the contour of the sides of the rail will be right lines, which will not only be parallel to the right line, which is the projection of the symmetrical plane, but will be equidistant from that right line, and on contrary sides of it: therefore, through any point s in $s s'$ draw $a f$ perpendicular to $s s'$, and make $s a$ and $s f$ each equal to half the breadth of the back of the rail. Draw $a a'$, $f g$ parallel to $s' s$, meeting the circle $a' g f' o$ in a' and g and $a a'$, $f g$ will be the projections of the sides of the straight rail.

Let $a b c d e f r u$ be a right section of the straight rail so placed with regard to the line $a f$, that $a f$ may be the greatest horizontal dimension of the right section of the straight rail: hence the right lines in the section which are perpendicular to $a f$ will be in planes parallel to the plan which divides the rail and cap into two symmetrical parts, and therefore the projections of these planes and the ordinates of the right section of the rail will all be in right lines parallel to $s s'$.*

The figure $a a' a f' g f$ may be considered as the projection of the surface S, as well as the projection of the rail and cap, and $a' f'$ may be considered as the intersection of one of the mitring planes in the surface S; therefore the ordinates upon $a' f'$ will be equal to their corresponding ordinates upon $a f$. Hence through any point p whatever in $a f$ draw the right line $p p$ parallel to $s s'$ to meet $a f$ in p. Draw $p b$ perpendicular to $a f$ meeting the curve or outline of the right section in b, and draw $p' b'$ perpendicular to $a' f'$. Make $p' b'$ equal to $p b$; then the points a', b', f are in the curve of the circular cap. In the same manner may be found a number of points through which the curve may be drawn with sufficient accuracy; this being done $a' b' c' d' e' f' r' u'$ is the section of the mitre cap required.

Section II.

Hoppers of mills.

The construction of columns and the hoppers of mills in wood, whether mitred or dovetailed, depend upon that principle of the trehedral in which the two right faces are given, to find the inclination opposite to one of them or adjacent to the other, and as such subjects frequently occur in practice, one or two examples will be useful to the student in this branch of the art of construction.

Example. Fig. 9 exhibits the two projections of a hopper joined together in the form of a regular square pyramid. The horizontal projection containing the plan being parallel to the square base of the pyramid, and the vertical plane containing the elevation being parallel to one of the edges of the base and perpendicular to the adjacent edges. The base will therefore be projected into a square, and the elevation into an isosceles triangle. Let the plan be A B C D and the elevation E F G; the right line E F being the elevation of the base A B C D. In the plan draw the diagonals A C and B D intersecting each other in the point H and draw H i perpendicular to H B. Make H i equal to the height of the pyramid h G in the elevation, and join B i.

We have now given the angles of the two right faces H B i, h B C of a right trehedral, to find the dihedral angle opposite to the right face H B C.

From any convenient point H in the diagonal B D, draw H j perpendicular to B i meeting B i in j, and draw H C perpendicular to B D meeting B C, or B C prolonged in C. In B D make H k equal to H j and join k C. Then H k C is the angle of the mitre, and the double of the angle $h k$ C will give the angle of the abutment of the dovetail joint.*

Fig. 10 exhibits the two projections of a regular octangular pyramid according to the foregoing positions, and as the diagram will agree with the same explanation it would be unnecessary to proceed further. The accented letters in the two diagrams 9 and 10 are affixed to pyramids of less height, and show the method of finding the angle of the mitre more clearly.

By this means a solid of revolution approaching in figure to the frustum of a right cone may be constructed with a series of thick battens of wood.

For the frustum of a pyramid of which the bases are regular polygons may be formed so as to be easily converted into that of a right cone. By increasing the number of sides, and by making the planes of the sides at equal angles with the planes of the bases, this conversion will be more easily effected.

And since this frustum is evidently the figure of a roof hipped on all sides, having the planes of the covering at equal angles with the plane of the horizon, and the outer edges of the tops of the walls in the form of a regular polygon, the angle contained by any two adjacent planes of the sides of the pyramid will be found in the same manner from the angle made by two sides of the polygon, and the inclination of the face of the pyramid to the plane of the base, as the angle at the hipped edge of a roof is found from the angle made by the two adjacent walls, and the angle made by any of the sloping sides of the covering, and the plane of the top of the walls.

With respect to the polygonal frustum under consideration, the angle contained by the planes of two adjacent sides being found, the half of it will be the dihedral angle made by the outer face and the surface of the edge of each batten. The length of each batten at the edge will be found in the same manner as the length of the hip line of a roof, and the breadth of a batten at each end will be equal to the side of the polygon at the corresponding end.

* Let us now suppose a surface passing through the solid of the rail and containing the right line $a f$ to be called the surface S; and let us suppose a vertical plane intersecting the surface S, and passing through any point whatever in $a f$ parallel to the plane of symmetry to be called the plane P, and let the intersection of the plane P and the surface S be called the intersection I; then let the intersection I in the plane P divide the section of the rail in the plane P into two such parts, that the part between the intersection I and the back of the rail may be everywhere of the same breadth; then every right line perpendicular to the surface S, comprised between the surface S and the curved surface of the cap, will be equal to the right line in which the cylindric surface which contains the perpendicular, and of which the axis of rotation is also the axis of that cylindric surface, meets one of the planes of the mitre.

* Sometimes for want of room it may not always be convenient to use the entire distance h G, figures 9 and 10, and since all that is required is to find the angle H B i of the vertical face: therefore in the case of more room being required, draw from any convenient point s in the elevation $s m$ perpendicular to E F meeting E G in m, and draw $s n$ perpendicular to E F meeting B D in n. Draw $n o$ perpendicular to B H, and make $n o$ equal to $s m$. Join B o, then B o and B i are in the same right line; hence h B o and h B i make the same angle. Draw $n s$ perpendicular to B i meeting B i in s, and in B H make $n l$ equal to $n s$. Draw $n e$ perpendicular to B H meeting B C in e, and join $l e$. Then the angles $n s$ C and $n l e$ are equal.

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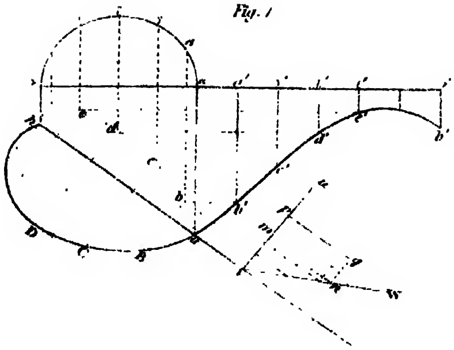


Fig. 1

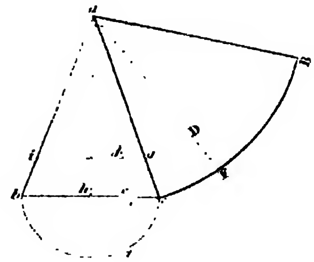
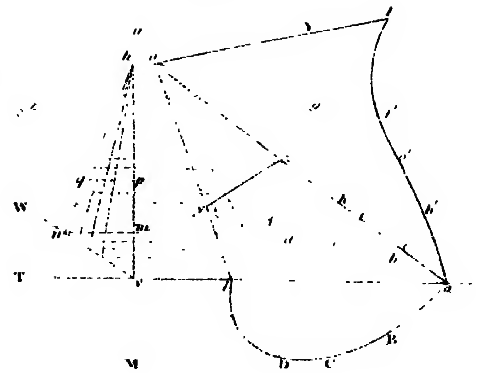


Fig. 2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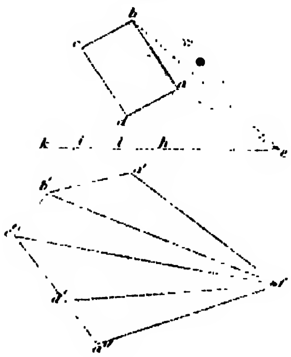
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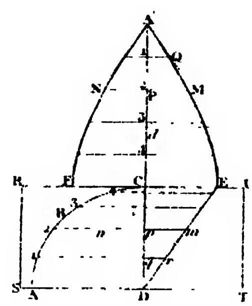
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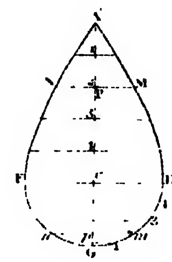
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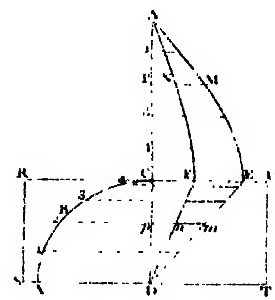
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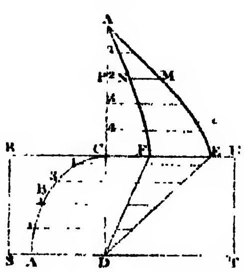
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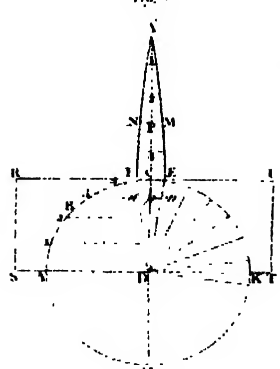
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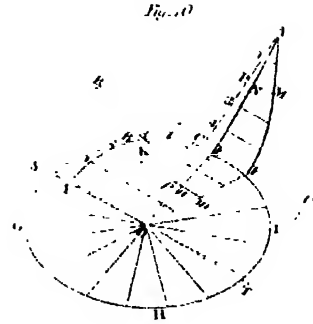
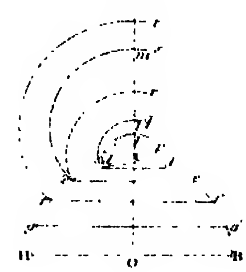


Fig. 10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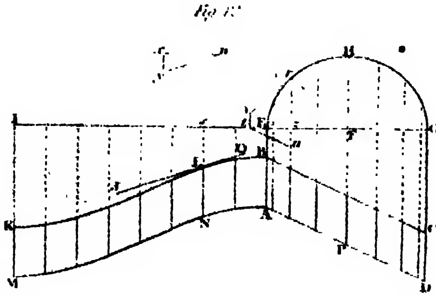
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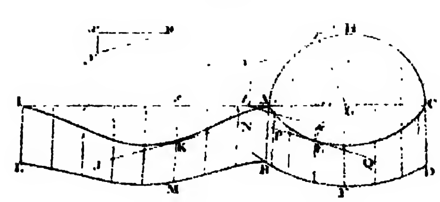
Fig. 13

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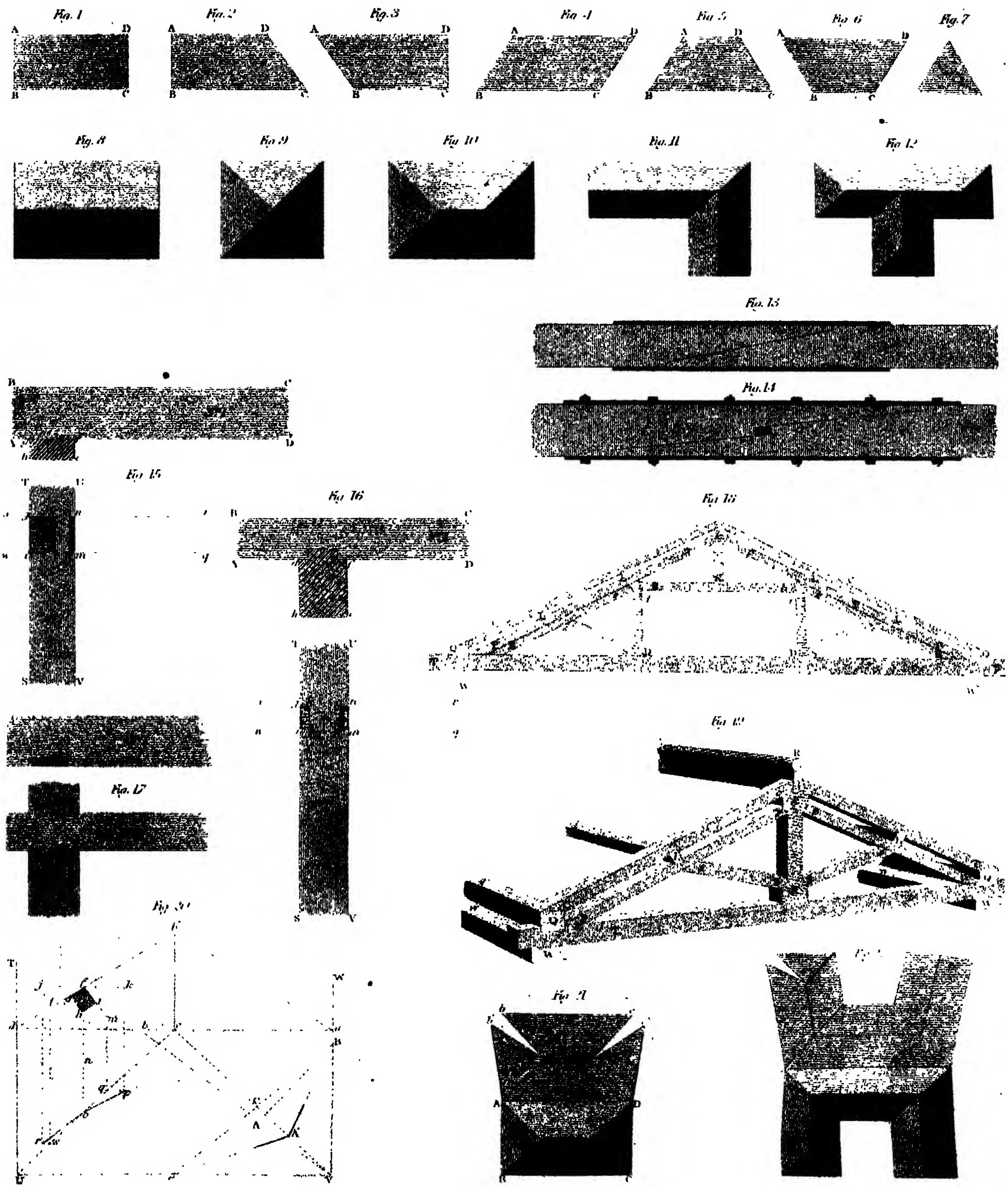


Fig. 2

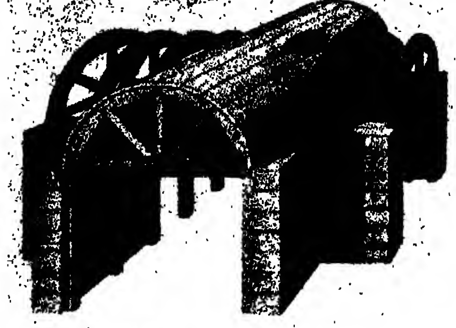


Fig. 3

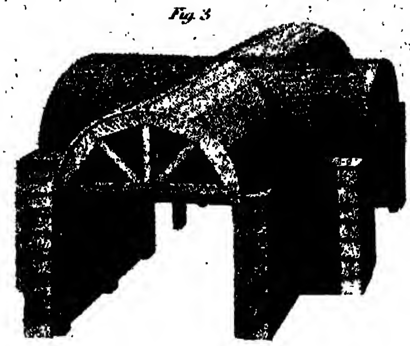


Fig. 7 Fig. 8

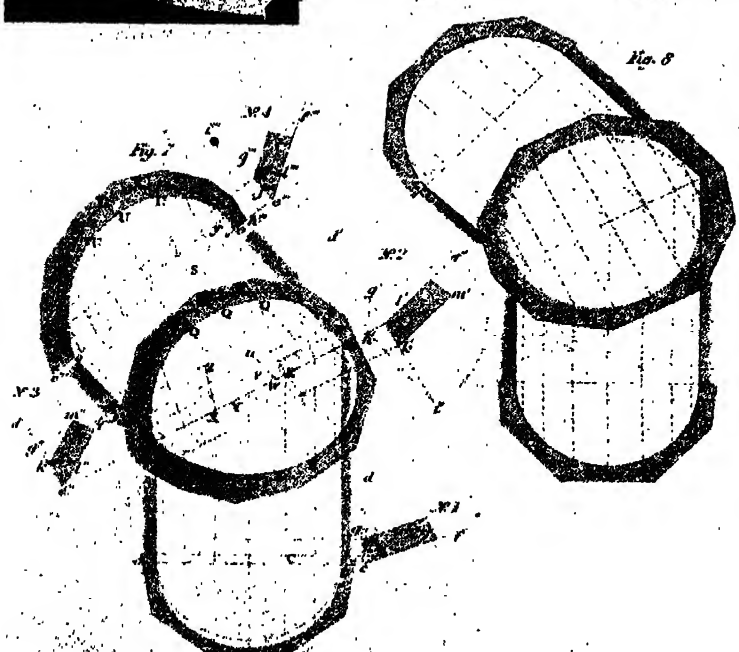
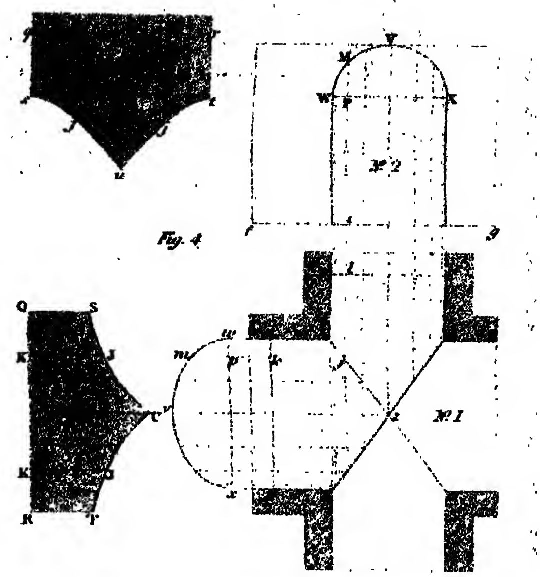


Fig. 4



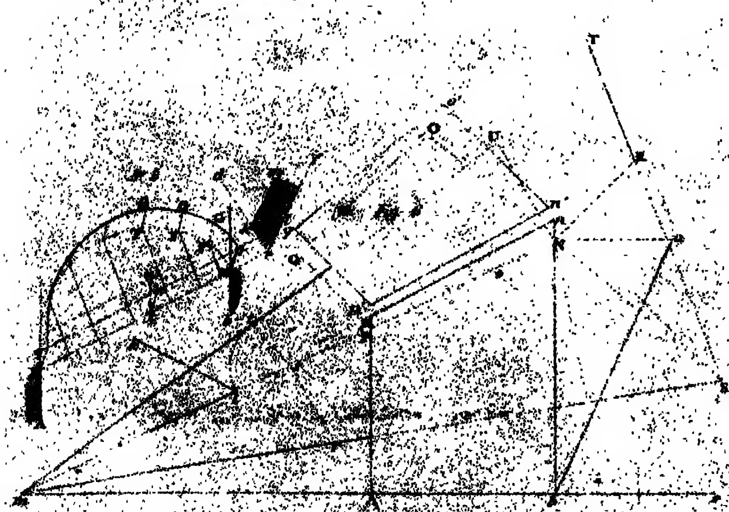
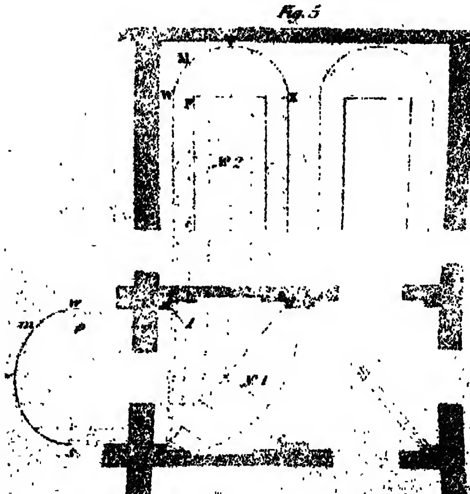


Fig. 5



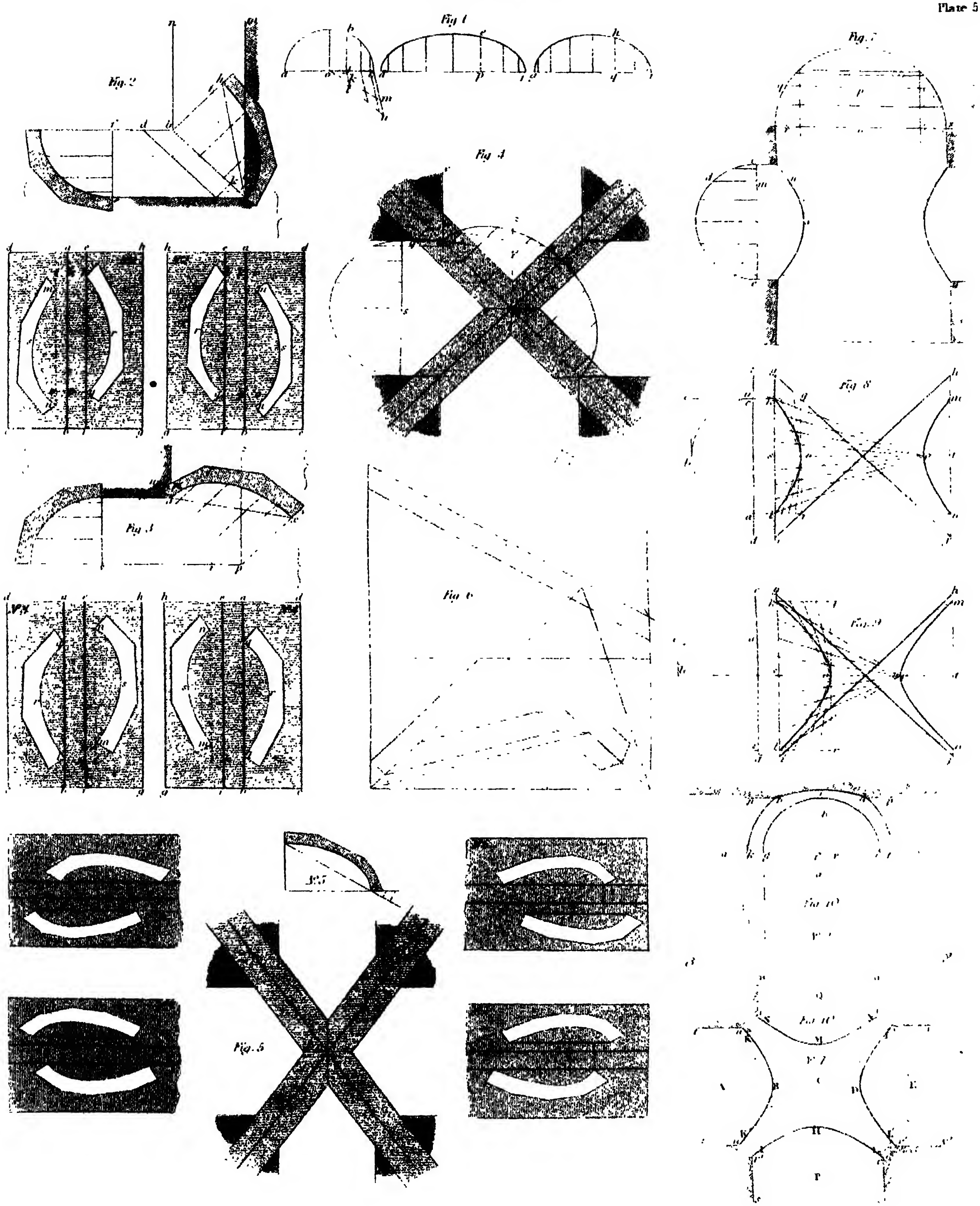


Fig. 1
Fig. 2
Fig. 3
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Fig. 10

CARPENTRY.

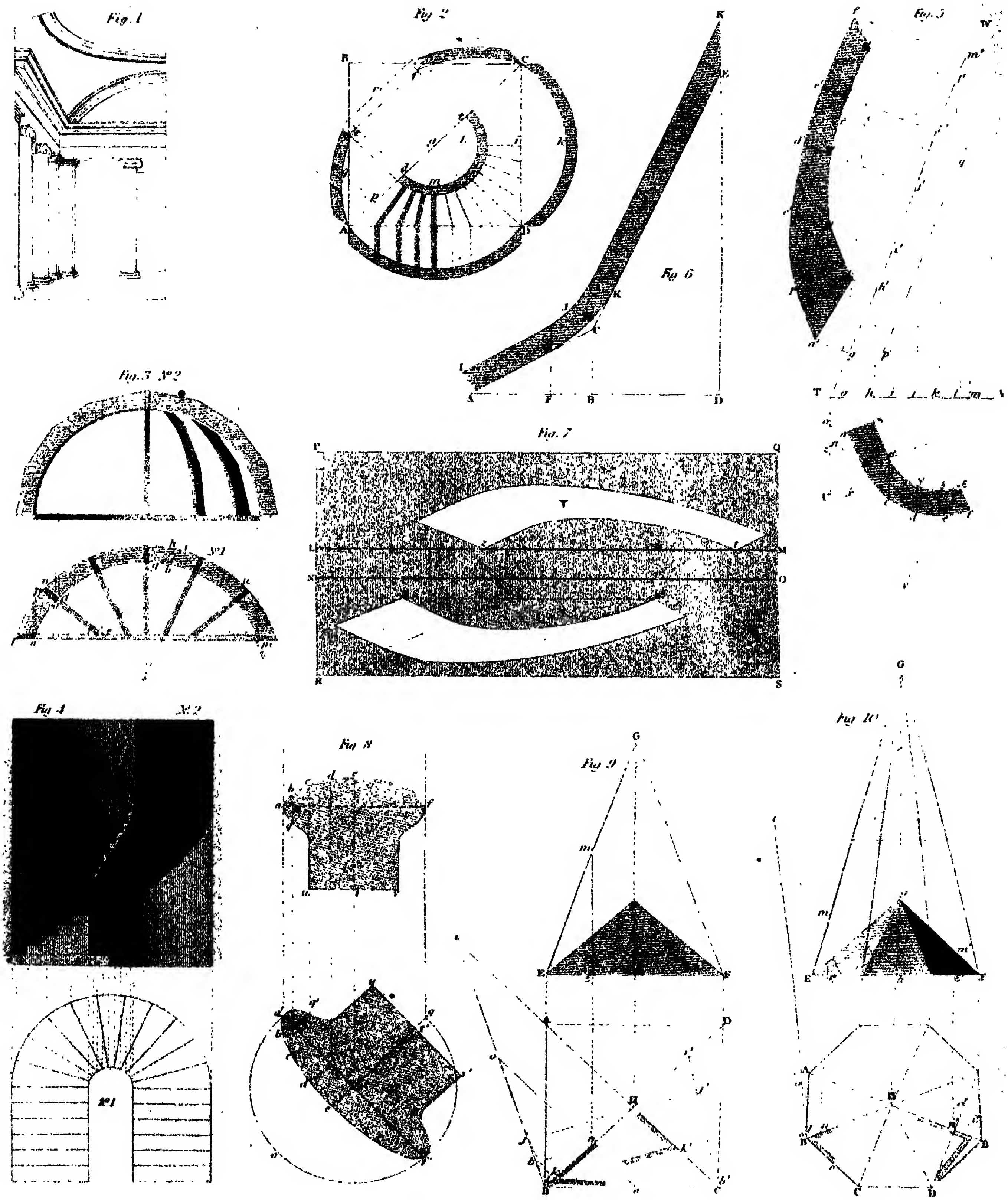
Fig. 1
Fig. 2
Fig. 5
Fig. 6
Fig. 3 No. 2
No. 1
Fig. 7
Fig. 4
No. 2
No. 1
Fig. 8
Fig. 9
Fig. 10

The battens being all properly diminished, and the surfaces of the faces and edges made to form the angle required, the parts when joined together will be the frustum of a pyramid, which will be easily converted into that of a right cone by reducing the angles and thereby leaving a regular curved surface in place of them.

Hence the shaft of a column may easily be constructed upon this principle; first, by making it in the form of the frustum of a pyramid, and then by rounding off the angles.

The following observations on the application of the principles to practice will be found of signal use to the young architect, builder, or workman.

A working drawing is a representation of the whole or of some part of a building on a plane surface, and may either be a plan or elevation, a section or a developement of the parts required to be put in execution. The constructive lines in Carpentry are generally developements of certain difficult parts of an object or building. A developement, though drawn upon the same plane, consists of one or more sections of the object in different planes, these sections being supposed to be raised to the proper angles which they make in the object itself upon certain lines which are in the plane upon which the drawing is made.

Having fully explained the theory and practice of Carpentry and Joinery, the reader will now be prepared to apply the principles of this theory to real buildings. In conclusion, it may be useful to give a short connected abstract of the whole principles before enumerated, and to point out their applications to practice.

Developable surfaces of cylinders and cones are not only applied to the formation of arched soffits in the apertures of doors and windows, but also to the coverings of circular roofs and domes. Pliable moulds made with such surfaces are used in Joinery for the construction of hand rails, and in masonry to form the conical beds of the stones of a dome, and the intrados of the stones of an oblique arch.

The sections of solids are applied in constructing the angle ribs, brackets of roofs, groins, and of coved ceilings.

The trehedral is applied in roofing to find the angles at the junctions of the timbers and the backings of the hip rafters, as also in masonry to form the beds of the stones of oblique arches.

FORTIFICATION.

Fortification. Definition of the ART or SCIENCE of FORTIFICATION.

FORTIFICATION, in the strictest acceptance of the term, is usually limited to the *Art* of constructing such works of defence, as may enable a body of men to maintain the possession of a city, or of any military post or line of country, against the assaults of a superior numerical force. But in a more enlarged sense, Fortification embraces also the *Science* of attacking and defending the constructions which it creates; and in this view, therefore, its uses involve a very principal part of the whole business of warfare. The Art of fortifying has often been eulogized, by its professors at least, as that exercise of martial skill which merits the unqualified applause of humanity: by reason of its being employed for the protection of the feeble against the oppression of the strong. The severer judgment of History will detract from much of this boast. Fortification, at the most favourable estimate, must only share the praise or reproach which justly attaches to the military Art in general, according as it is honoured or disgraced by the purposes to which it is devoted. Defensive structures were, doubtless, originally the resource of the weak: but they have been full as often erected to rivet the yoke of conquest and servitude, as to cement the proud security of a free people; nor, in the confusion and frequency of international wars, would it be easy to measure the moral benefits of an Art which, obeying the shifting vicissitudes of human events, is used alternately to resist invasion and to consolidate tyranny.

Proposed division of the subject.

Such considerations may be safely abandoned to the idleness of professional enthusiasts: they tend to no practical result, and suggest no lessons of improvement. As a preliminary to any attempt to give an acquaintance with the general principles of Fortification in its present state, it is far more interesting and useful to trace the progress—or, as a lively foreign writer has termed it, the Natural History—of the Art through its connection with the military and political fortunes of Empires; and before, therefore, we enter into some analysis of the existing principles of warlike constructions and the established rules of Science by which they are assailed and defended, we shall endeavour to prepare the reader for a clearer comprehension of the subject, by a rapid sketch of the changes which the method of fortifying has undergone in different Ages of the World.

PART I.

HISTORY OF THE ART OR SCIENCE.

CHAPTER I.

Fortifications of the Ancients.

Obvious origin of Fortification.

In this retrospect to the earliest known modes of defence, we shall not imitate those Writers who have imagined it necessary to elucidate with oracular wisdom the origin of Fortification itself. Unquestionably we shall not deny, and still less shall we proceed to prove, the grave and palpable truism which such profound reasoners have laboriously enunciated:—that the Art of fortifying owed its primitive necessity and its rise to the violence and the wickedness of mankind. We may be content with the assurance, that the same want of individual security against the oppression and rapine of the stronger, which in the rudest stages of Society kept men united in families and communities, would dictate the first expedients for collective defence; that the same Art which reared the first hovels for human habitation, would prompt the idea of encircling the congregated dwellings of the Tribe for the public security with a wall or a fence of similar materials and structure. The nightly depredations of wild beasts, the incursions of human enemies hardly less ferocious, would equally suggest to the most untutored Savages the necessity of such an enclosure for the protection of their flocks and herds, their women, their children, and themselves. In a word, the impulse of self-preservation, which is implanted by Nature in the human breast, would teach men in their wildest state to oppose to the fierce inroads of brute force such obstructions, as might place their lives and property in security from sudden destruction, and compensate for disparity of numbers and physical strength. Those obstructions, whatever might be their form or kind, were, in effect, Intrenchments; and the craft which disposed and fashioned them already constituted the Art of Fortification. That Art may therefore be said to have originated with Society itself; the first expedients for its improvement would be contemporary with the earliest efforts of human ingenuity and contrivance; and, it need not be added, that its principles of construction have always kept pace with the general progress of Civilization and the discoveries of Mechanical Science.

First expedients for defence.

Their materials and form.

It would not, perhaps, be very important to determine with exactitude, even if we possessed the means of so doing, the nature and form of the very earliest fortifications. But we shall probably collect a sufficient idea of their qualities, by the analogy which may be supposed to subsist between them and the rudest essays of the Art, observable among the savage people of different quarters of the Globe in recent times. The materials of the most ancient and simple fortifications were, no doubt, those on which, indeed, the modern engineer, with all his science, is still obliged, in his field operations, chiefly to rely:—earth and wood. To clubs and stones, the first offensive weapons among Barbarians, a bank and ditch, or a single row of strong

Fortification.

stakes, or trunks of trees, might offer a more than sufficient resistance. But as soon as the assailant learned also to assist his animal strength with even the simplest expedients of Art, additional solidity and ingenuity became requisite for security in the construction of works of defence.* In New Zealand, Cook observed the *hippahs*, or village-forts of the natives, placed on heights and in commanding situations, but consisting of only a single enclosure of trunks of trees strongly and closely set on end in the ground, with a slight inclination inwards. This fence was lined at intervals by interior platforms or stages raised to within three or four feet of its summit, from which its defenders, themselves covered to the breast, could hurl their stones and javelins on the assailants below. At the outset of the conquest of Mexico, Cortes and his followers (A. D. 1519) found the defences of Tobasco, a town of some size on the American Continent, yet more simple in construction than those which we have instanced among the Savages of New Zealand. That Indian fortress was composed of only a circular enclosure or stockade of large trunks of trees set upright, with small apertures through which arrows might be discharged.† The ancient intrenchments of Kani Sigeth, and Temiswar, in Hungary and Turkey, as they existed so late as A. D. 1700, are said to have afforded a specimen of barbarian Art but a step more advanced. These consisted of a double line of strong piles, having the interval between them filled with the earth of the ditch which had been excavated in front; the outer row of piles being left highest, to serve as a sort of parapet or breastwork for the defenders on the terrace or rampart. A remarkable similarity to this construction was shown in the intrenchments of the Burmese during our late war in Ava. Their common breastworks were formed of a double line of stakes or hurdle work, the intermediate space of which was filled with earth; and their stockades or palisaded redoubts from ten to twenty feet high, whose assault in an uncleared and difficult Country cost the lives of so many of our gallant Countrymen, were built much in the same manner as those ancient Hungarian works.

Progress of the Art.

Such examples may suffice to exhibit the natural infancy of the Art in all Countries and Times. The next improvement in military defence would obviously be coeval with the first employment of masonry in Civil Architecture. Against the assaults of an enemy unprovided with ponderous missiles, a simple wall of stone or brick would form a more lofty and durable rampart than intrenchments of earth or wood; its height would increase the difficulty of escalade; and the invention of battering engines for its demolition would only impose the necessity of an additional thickness and strength in its construction. But the defence was still extremely defective, as long as the besieged, from behind the summit of their wall, were altogether unable to see the assailants at its exterior base; and this inconvenience produced the expedient of a flanking or side defence:—a condition that may be said to form the main principle of the Art. To obtain a flanking defence for the wall, massive towers of masonry were built at all its angles and on each side of its gates; and these towers besides being made to project for that purpose in front of the wall, were constructed of superior height so as to command or overlook every part of it. The use of towers, indeed, in Fortification may be pronounced of immemorial antiquity: for there are innumerable notices of their existence on the walls of fortresses in the earliest records, sacred and profane: in the Historical books of the *Old Testament*, and in the *Iliad*. In later Ages they were made sometimes square, hexagonal, and octangular: but the preference was generally given to the circular over any of these forms, as best adapted to resist the shock of battering engines.*

Walls and towers of masonry.

See plate ii. fig. 2.

Immemorial antiquity of such defences.

Machicoles

Another invention of uncertain but less remote date was employed to increase the power of the *direct* defence, and to enable the besieged to see down to the base of the towers and walls. Along the summit of all the works, and overhanging the main mass, was constructed a narrow gallery, supported by *corbels* or stone brackets, through the pierced floor of which every kind of missile might be showered upon the heads of the assailant below, who should attempt either to scale or undermine the walls. These *machicoles*, or projecting galleries, still presented to the country the parapet or battlement that always crowned the walls, with apertures for the discharge of arrows and javelins at the assailants in front; and a lower gallery also often ran through the thickness itself of the wall near its top, pierced with loopholes for the same purpose, and arched and open towards the interior.† A wide and deep moat, either filled with water, or dry where the level of the Country denied that resource, swept round the whole circuit of the walls, and completed the defence.

and moats.

For an idea of the general appearance of ancient fortresses, see plate i. fig. 1.

Such, whatever variety there might be in the details, and whatever gradual improvement in the process of construction, continued the general character of fortresses and the principles on which their defence was regulated, from almost the earliest epochs of authentic History even until after the invention of gunpowder. The walls of Pæstum, which are pronounced by the best Classical Antiquaries to belong to a period far more remote than the Age of Grecian civilization, are surmounted at intervals with the circular tower; and these stupendous remains do not differ greatly as fortifications from the structures of much later times. This common agreement of the modes of defence, which seems to have obtained at a very distant Age throughout the Western parts of Asia, and the European and African shores of the Mediterranean, may justify the opinion that the first improvements in Fortification, as in other Arts, were derived from the East But whatever was the origin of the general system of fortifying among the civilized Nations of Antiquity, it was from the vigorous intelligence and warlike spirit of the Grecian and Roman mind, that it attained all the perfection of which it was susceptible, whether in attack or defence; and it is in the records of the achievements and knowledge of those People alone, that we can gather the traces of the ancient Science.

It would, however, be to little purpose to fatigue the

* As an ancient example of this first improvement in Fortification may be mentioned the strong-hold of the Drilians, a People who inhabited the shores of the Euxine: this is described by Xenophon (*Anabasis*, lib. iv.) as surrounded by a ditch and rampart, on which were palisades and wooden towers.

† B. Diaz de Castillo, *Hist. de la Conquista de la Nueva Espagna*, c. 34.

* Vitruvius, book i. c. 5.

† Such a passage still appears in the remains of Aurelian's walls at Rome. Newton *on Vitruvius*, lib. i. c. 5.

A modern traveller describes a similar kind of gallery with apertures for the discharge of missiles in the ruins of the walls of Tirynthus near Argos, a construction of great antiquity. Hughes, *Travels in Greece*, &c.

Fortification.

Fortifications of the Greeks and Romans.

general reader with minute details, even from Grecian and Roman examples, of the ancient system of fortifying; and a very few further remarks on its conditions will be all we shall offer. In the tracing or ground-plan of the works, it does not appear that any fixed rules were followed, as in modern constructions.

Configuration,

The configuration of the walls was usually determined by the accidents of the site; or if any general disposition was preferred, it seems to have been merely an irregular succession of salient (or projecting) and re-entering angles, flanked by towers. This arrangement, from its frequent adoption, must have been generally considered most advantageous for an obstinate defence: though Vitruvius* recommends the outline which most resembles a circle, and proscribes very salient angles as easiest to attack and most difficult to defend. Under any circumstances it was a natural rule that the towers should not be further apart than the range of the ordinary missiles of the infantry in order that every part of the intervening walls might be covered by their flanking discharge.†

height, and

The height of the walls seems never to have been determined by any general rule, and differed in all sorts of examples and circumstances. Herodotus‡ gives to the ramparts of Babylon the enormous elevation of three hundred and fifty feet. Xenophon§ says the works of Larissa on the Tigris were one hundred feet high, and those of the Median wall near Babylon of the same elevation.‖ But, without multiplying citations, it may be sufficient to observe, that modern commentators have been led to consider about one hundred and twenty feet as the mean height of the ramparts of Antiquity; and it is only in Asiatic constructions, which seem usually to have been formed on more gigantic proportions than those of Europe, that many instances are recorded of a greater elevation.

thickness of their walls.

The thickness, like the height, of walls was various: but to afford space for the passage of armed men on the summit behind the parapet or battlements, and through the lower galleries, as well as to resist the assaults of the battering ram, it could scarcely in any case be less than eight or ten feet. But it was certainly often far greater; nor for the placing and working of the defensive engines could that breadth have sufficed. It has been disputed, indeed, in what manner these engines were disposed, and doubted whether they were ever placed *on* the walls: but though such as threw stones might cast their missiles from interior terraces or mounds over the walls like the modern mortar, there were others, for the discharge of darts and iron-pointed beams, which must assuredly have been used, with a horizontal or *point-blank* direction, through apertures on the summits and in the thickness of the works.¶

Breadth of rampart required.

It was doubtless for the purpose of obtaining a more spacious rampart for the placing of these engines, as well as for increasing the power of resistance to the battering ram, that the expedient of raising an inner wall of masonry parallel to the outer, and filling the interval with rammed earth and rubbish, was often adopted. Thus the walls of the Piræus and of Byzantium were twenty feet broad; those of Nineveh thirty feet; and those of Babylon, which are described by Historians as seventy feet in thickness, were probably built in this manner. The ramparts of Bourges were forty feet thick; and Cæsar has detailed their mode of construction, which he declares was common to almost all the Gaulish cities. They were built of trunks of trees laid in horizontal rows, two feet asunder across the thickness, and of alternate courses of stones and well-trodden earth; and the outside of the rampart was clothed with a thick wall of masonry, in which the ends of the beams were imbedded. This mode of building was admirably adapted for a good defence; because the timber resisted the efforts of the battering engines, while it was secured from conflagration by its admixture with the earth and stone.* Vitruvius recommends the use of scorched olive piles for the same purpose; as that wood is unaffected by the weather, by rot, and by age. But in the most massive constructions, he advises the introduction of transverse walls to bind the external and interior faces of the rampart, disposed between them either perpendicularly like the teeth of a comb, or obliquely in the manner of those of a saw.†

Double and triple circuit of walls.

When a city happened not to be advantageously situated for resistance, or when its wealth and importance suggested a more elaborate provision for defence than a single circuit of towers and walls, a double or even triple envelope of works was constructed. Of these we have instances in Jerusalem and in Rhodes; while Ecbatana, the Capital of Media, was surrounded with no fewer than seven enclosures of rampart.‡ A citadel in the interior of a fortress, or formed on the least accessible part of its circuit, was as common a resource, for securing a last refuge to the garrison, or for overawing the citizens themselves if disaffected, as in modern times. And, not unfrequently, the several quarters and suburbs of a large city formed so many distinct fortresses: while sometimes a chain of detached works covered the heights which commanded the approaches to the place, or, in maritime situations, defended the entrance of ports, or the mouths of rivers.

Example of Syracuse.

For a single example, exhibiting all these provisions of defence, we need only cite the fortifications of Syracuse, which Nature and Art had conspired to render one of the strongest places of antiquity, and which deserves particular notice in Military History for its B. C.
resistance in three memorable sieges to the arms of the 413.
most warlike and scientific assailants of the times—the 396.
Greeks, the Carthaginians, and the Romans. 212.
In all these sieges, of which the first and last (by the Athenians

* *Ubi suprà.*

† This range probably did not, in general, exceed one hundred feet; and for one example we find in effect that the distance between Cæsar's towers in his lines before Alesia (not at the siege of Bourges as Newton has erroneously stated) was eighty feet. *De Bello Gallico*, lib. vii. The wooden towers constructed to strengthen the intrenchments of armies were, however, frequently further asunder; those raised by Philip of Macedon at the siege of Thebes in Phthiotis were one hundred paces from each other. Polybius, lib. v. c. 9.

‡ Lib. i. c. 98.

§ *Anabasis*, lib. iii.

‖ *Idem*, lib. ii.

¶ Among the Romans there was an express distinction even in terms between the *embrasures* or mere openings in the battlements at the top of walls, and the *port-holes*, or apertures, with which the successive stages of the towers were pierced: the former were called *crenæ*, the latter *fenestræ*. From Cæsar we find positive evidence that, in towers of attack, engines were placed which discharged their missiles through port-holes. In the tower raised at the siege of Marseilles, it is said, *fenestrasque quibus in locis visum est, ad tormenta mittenda struendo reliquerunt. De Bello Civili*, lib. ii.

* Cæsar, *De Bello Gallico*, lib. vii.

† Parts of Constantine's walls at Rome show the remains of such transverse walls. Newton on *Vitruvius, ubi sup.* note 7.

‡ Herodotus, *ubi sup.*

Fortification.

under Nicias, and by the Romans under Marcellus) must be familiar to every reader, the defence may be declared to have been successful: the besieging armament of the Carthaginians under Imilcon, like that of the Athenians under Nicias, was repulsed and destroyed;* and it was not until the genius of Archimedes had baffled the assaults of the Romans, and long after they had been compelled to convert the siege into a blockade, that Marcellus carried the place by surprise. The main-land City of Syracuse was seated on the Northern side of its fine port, at the entrance of which lay the Island of Ortygia, (*a*) separating it into two harbours; the lesser, or that between the Island and the City, being thus divided from the rest of the bay. Ortygia constituted the chief maritime defence of the City; it contained the citadel and arsenal, insured the command of the two ports, and was therefore altogether so much regarded as the key of the whole City, that the Romans, after obtaining possession of the place, never suffered a Syracusan to inhabit it. Between the first and second sieges, Dionysius the Elder built a dam from the main-shore to the Island across the inner entrance of the little harbour, by which it had communicated with the great port; while the passage from the sea was closed by a wall or pier, with gates which admitted only a single vessel at a time. The little port, which was capable of containing sixty of the largest war-galleys, was thus, in fact, completely embraced within the fortifications. The entrance of the great port from the sea was likewise, at a later period, defended as well by a strong fort (*f*) on the Southern main-land promontory of Plemmyrium, as by that end of the Island; while the castle of Olympiæum (*g*) at the bottom of the bay further commanded its interior shore. The main-land City of Syracuse itself was composed of four distinct quarters, each fortified separately, while the whole was enclosed by a common envelope of lofty walls and towers: Achradina (*b*) facing the sea to the East, and forming the whole lower breadth of the City; Neapolis (*c*) and Tychë (*d*) adjoining it, and presenting their exterior walls to the "great port" and the North respectively; and Epipolæ (*e*) crowning the Westward heights. The security of the last quarter, which was almost encircled by nature with a chain of crags and precipices towards the country, had been strangely neglected; so that the Athenians, in the first siege, were suffered to establish themselves in it: but it also was fortified by Dionysius with such strength as to cover the lower quarters of the City, and to render the heights themselves, and the whole place, impregnable from that side.

See pl. ii. fig. 3.

Ancient modes of attack.

After this brief and general explanation of the ancient manner of fortifying, it is necessary to offer a similar illustration of the mode in which the attack of places was conducted. In the ancient, as in the modern Science of Fortification, the system of attack was naturally regulated according to the method and form of defence which it was requisite to overcome. In the absence of any sufficient means of forcing a passage through a solid rampart too lofty for escalade, the first expedient, perhaps, which might present itself to an assailant would be, to commence a mound or bank of earth before the place, to increase and carry forward the mass until it touched the walls, and was raised to the level of their summit, and thus to pour his whole force of numbers over the defences upon the besieged. Such, accordingly, we find was the earliest mode of attack which is recorded in the authentic History of Mankind; and such, indeed, continued to be one of the common expedients of assault, even in the most scientific Ages of Classical Antiquity. A passage in Holy Writ seems clearly to point to the existence of this mode of attack, even as early as the Age of Moses, fifteen centuries before Christ, where the Israelites are commanded, in besieging a city, to cut down such trees only as are not fruit-bearing, and to "*build bulwarks* against the city" until it be subdued;* but yet more expressly the denunciation against Sennacherib, King of Assyria, that he "should not shoot an arrow into Jerusalem, nor come before it with a shield, nor *cast a bank against it*,"† proves that, at least seven hundred years before Christ, this was the ordinary process of a siege in the Countries of the East.

2. By battering and missile engines.

At what period the next contrivance which might occur to a besieger was invented—that of machines for effecting an entrance into the place by beating down a part of the walls, or the use by both parties of great engines for hurling masses of stone and other missiles upon their adversaries, it is difficult to determine. These inventions were probably not known in the Age of Homer, since no mention of them is made in the *Iliad*, where their use would naturally have found a place in the vivid picturing and minute description of the combats before the walls of Troy. But in Sacred History we find them numbered, within four hundred years after the era of the siege of Troy, among the means provided for the defence of Jerusalem by King Uzziah, (about B. C. 800,) who "made in Jerusalem engines invented by cunning men, to be on the towers and upon the bulwarks, to shoot arrows and great stones withal."‡ It is, however, probable that such engines were not then for the first time constructed; and we may therefore refer their invention to an intermediate period between the collection of the Homeric Poems and the reign of Uzziah in Palestine, that is, about a thousand years before the Christian Era.

Process of an ancient siege.

After these references to the obscure practice of remote Antiquity, we pass at once to the mature state of the Science of offensive and defensive Fortification, as exhibited in Grecian and Roman warfare. It would far exceed our limits, and otherwise, indeed, it would not answer any useful purpose, to mark with chronological precision the fluctuations of the Science during what are commonly understood as the Ages of civilized Antiquity, from about the great Persian invasion of Greece to the fall of the Western Empire of Rome; and, therefore, in briefly describing the process of an ancient siege, we shall refer less to examples of any particular epoch, than to the general perfection which was attained in the whole period. In commencing a formal siege on a great scale, the first operation of the assailants, or mode of investing a city, was to draw round it a double line of earthen intrenchments or ramparts: the one facing the country, the other the place; and the intermediate space forming the camp, and containing the troops, the

Lines of circumvallation and contravallation.

* Diodorus Siculus, lib. xiv. c. 61—73.

* *Deuteronomy* ch. xx. ver. 20.

† 2 *Kings*, ch. xix. ver. 32. So also an expression in Jeremiah identifies the sense of the two passages above quoted: "*Hew ye down trees* and *cast a mount* before Jerusalem." ch. vi. ver. 6.

‡ 2 *Chron.* ch. xxvi. ver. 15. We believe that a passage in *Ezekiel*, about two hundred years later, contains the earliest express mention by name of the battering ram, that is any where to be found. *Ezek.* ch. iv. ver. 2.

Fortific

engines, and the whole *matériel* or stores of the besiegers. The object of the outer circuit, or line of *circumvallation*, being to prevent the introduction of supplies to the garrison, or the relief of the place by an army from without; that of the inner, or line of *contravallation*, to confine the besieged to their walls, and secure the camp from their sallies. Against a place of great strength, or whenever the design was rather to reduce the besieged to the necessity of surrendering by the slow operation of famine, than to carry their defences by rapid assault, both the lines of circumvallation and contravallation were built with flanking towers at intervals, like regular defensive fortifications; and this laborious and tedious process of permanent blockade was, in fact, only the partial or entire enclosure of the fortress besieged within a second of similar construction. The distance of the circumvallation from the place was usually from nine hundred to one thousand yards; and both Greeks and Romans seem in all cases to have given great care and solidity to the formation of their intrenchments. At about six hundred yards from the place, a numerous guard was usually placed to repel sallies and protect the progress of the attack.*

Manner of approaching the walls.

Covered by these supports, the assailants, if an active siege were intended, began to carry forward their various works and engines of offence towards the walls. These were the mounds or *aggeres* already noticed; covered lines or galleries of approach and communication, being either excavated trenches or, more commonly, blinds of carpentry, hides, &c. the *vineæ* of the Romans; subterranean passages or mines; balistic and battering engines, the principal of which we shall enumerate; and, lastly, movable towers and other covered buildings, composed of strong timber, hides, haircloth, &c., on rollers and wheels. On the exact nature and form of several of these processes and constructions, modern opinions are much divided; and the laborious zeal of commentators has vainly endeavoured to illustrate satisfactorily descriptions of the ancient Writers, which, in the absence of plates, are necessarily obscure and uncertain, and which very few sculptured trophies or other monuments have survived to explain. In the last Century, particularly, the conflicting judgment of the military world was curiously excited in a controversy, which was first produced by the theory of the celebrated Chevalier de Folard. That enthusiastic soldier and devoted antiquary, with some Classical learning, and much professional knowledge, but with still more Imagination, endeavoured, in his Commentary on Polybius, not only to demonstrate the superiority of the Ancients in the whole Art of War, but to depreciate the efforts of modern strategical Science into a mere imitation of their principles and practice. In his theory, therefore, the operations of a modern siege seemed but the copy of the ancient attack: the balistic engines were disposed by his fancy, like batteries of cannon and mortars; the *vineæ* were the parallels and approaches of our modern trenches; the *aggeres*, cavaliers or raised intrenchments; and the mines similar in construction and purpose, to the appalling expedients of these gunpowder Ages.

Modern controversy raised on the subject.

Theory of the Chevalier de Folard,

Impugned by Guischardt.

The theory of Folard was assailed after his death by Guischardt,* a Dutch Officer of equal learning and cooler judgment, who exposed the extravagance of many of his conclusions, and established a superior reputation for accuracy and success as a commentator on the Military Art of the Ancients. In the degree in which he strained many passages from the Classical Authorities to the establishment of a favourite theory, no one, we believe, now doubts that Folard was wrong: but Guischardt, it can as little be denied, was led, in the usual eagerness of refutation, to the opposite extreme of error; and, in the conduct of sieges, at least, there are many more traces of coincidence between the ancient and modern practice, notwithstanding the vast change effected by the discovery of gunpowder, than he has always chosen to admit. In both, the object may be considered generally as the same, to effect a breach in the walls of the place; the aid of engines for the discharge of missiles was employed by the Ancients, like batteries of cannon and mortars in the modern parallels, to cover the progress of the attack, to ruin the defences, and to drive the garrison from the ramparts; and there was a close similarity in the object of the *vineæ*, whether galleries or trenches, with that of the parallels and approaches by the *sap*, in our times. The inferiority of the ancient means of attack to those of defence, is a far more remarkable distinction from the state of the modern Science, than is contained in any difference as to the mere order and design of the siege.

Aggeres

The nature and object of the ancient *aggeres*, or offensive mounds, we have already sufficiently explained. They were composed of earth, stones, timber, and all kinds of rubbish which could be collected; and constructed of immense mass and height with a labour and celerity—by the Roman legionaries especially—of which modern troops would probably be found altogether incapable. The *agger*, for example, raised by Cæsar's army at the siege of Bourges, was three hundred and thirty feet long or broad,† and eighty high; and he tells us that this huge work, notwithstanding the severity of the cold and perpetual rains, was completed, and advanced almost to touch the ramparts of the place, in twenty-five days. On the *agger*, the movable towers and balistic engines were placed, to overlook the walls and cast missiles upon the defenders; and the whole front of it was frequently screened with a strong blind of carpentry, covered with hides, hurdles, &c., to protect the assailants from the missiles of the garrison. At the siege of Jotapata by Vespasian, no less than one hundred and sixty engines were ranged along the *agger*; and several towers of carpentry were in the sequel also placed on it.‡ Finally, it should be observed that in some cases more than one *agger* was raised against the walls: as at Marseilles, where Cæsar's troops attacked two of the fronts of the place.§

Vineæ.

Of the *vineæ*, however composed, we may be contented to assert, that they were certainly the works of communication and approach which the Ancients employed in their sieges. The manner in which the term is used by the Latin Authors is often vague and indefinite; nor shall we stop to weigh the opposite arguments

* Cæsar always observed this precaution. See his declaration, especially at the siege of Bourges, lib. vii. "*Instituto Cæsaris duæ semper legiones pro castris excubabant.*"

* *Mémoires Militaires sur les Grecs et sur les Romains*, 2 vols. in 1, 4to. La Haye, 1758.

† In its parallel front to the walls, of course. *De Bello Gallico*, lib. vii.

‡ Josephus, lib. ii. c. 12, 13.

§ *De Bello Civili*, lib. ii.

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in the antiquarian schools of Folard and Guischardt on their nature. There can be no doubt that they were frequently mere raised galleries of carpentry, hurdles, hides, &c., as above noticed; and that they were sometimes movable sheds on rollers and wheels. But it is equally undeniable from several passages, that they were at least sometimes, as Folard has asserted them to have been usually, excavations like the modern trenches. Thus, for an example of either kind, it may, in the first place, be noticed that at the siege of Echinus in Thessaly by the last Philip, where the attack was made against two towers and the wall between them, the besiegers erected a tower of timber, covered by hurdles, opposite to each of those of the town, and of the same height; and between them was a connecting gallery similarly formed. From the camp to each tower was also a covered gallery; and all these galleries served to conceal the communications of the besiegers. A battering ram was placed on the ground-floor of each tower, and three batteries of *balistæ* were placed in front of the gallery between them.* But, on the other hand, we learn that, at the siege of Lilybæum, during the first Punic War, when the Romans invested both sides of the town, they connected their two camps by an intrenchment;† and we find that, at Dyrrachium, Cæsar carried forward his approaches against Pompey's lines, by works which unquestionably corresponded to the modern trenches,‡ or excavations for cover. That lines composed of the *vineæ* were often drawn opposite to the walls, where *aggeres* were not used, something in the manner of modern parallels of trenches, to contain troops for checking the sallies of the garrison, and covering the circuit of communication, seems also most probable, though there is no evidence that such was, as in modern Science, the established and regular principle of attack: but whether by such *vineæ* or covered lines, and approaches, are in every case to be understood either raised galleries of timber, &c., or sunken trenches of earth, is a mere idle quarrel of words.

Mines.

Though at what time mines were first applied to the attack and defence of fortresses is uncertain, there is evidence of their familiar use by the Ancients as early as the Age of Herodotus; and in the more advanced state of the Military Art we find them employed almost invariably in sieges. In the memorable defence of the little city of Platæa, in the Peloponnesian War, (B. C. 429—7,)—the first siege, as Mitford has observed, of which any connected detail remains in the annals of mankind,—Thucydides relates§ the attempt of the garrison to undermine the *agger* of the besiegers; and, on the other hand, the story in Livy,‖ of the mode in which the Romans effected their entrance into Veiæ, (about B. C. 393,) after a ten years' siege, by the mine, is in the memory of every schoolboy. The capture of Gaza by Alexander may suffice for a later example¶ of the successful use of the same process; and, in a subsequent Age, the walls of Palæa, in Cephalonia, and of Thebes, in Phthiotis, when besieged by the last Philip of Macedon, were undermined to the extent of two hundred paces in length.**

* Polyb. lib. ix.

† *Ibid.* lib. i. c. 3.

‡ *Intra has mediocri latitudine fossam tectis militibus obduci jussit. De Bello Civili*, lib. iii.

§ Lib. ii. c. 76.

‖ Lib. v. c. 19—21.

¶ Quintus Curtius, lib. iv.

** Polybius, lib. v. c. 1 *et* 9

Counter mines.

Nor were the preparations of the besieged, either to arrest the subterranean approaches of the assailants, or to employ the same expedients against them, always deferred to the hour of danger. Vitruvius* mentions the construction at Apollonia of something like a system of defensive, or *countermines*, carried out to the distance of a bow-shot from the walls, to discover the subterraneous approaches of the besiegers. In these galleries were suspended brazen vases, which resounded at the blows of the enemy's iron tools in their vicinity, and showed in what part their miners were at work. These contrivances thus answered the same purposes as we shall find the listening galleries of the Moderns, and directed the engineer of the garrison where to drive out his galleries to meet the enemy, and destroy his workmen from above with caldrons of boiling water, pitch, &c. The introduction of torrents of water and barrels of burned feathers, and other suffocating mixtures, into the mines of an opponent, was also a common expedient of destruction. Finally, it may be observed, that at Gamala in Judæa, during the war of Vespasian against the Jews, Josephus† appears, by his narrative, to have prepared, while in the service of his Countrymen, a regular system of countermines for the defence of that fortress, which were used with considerable effect against the approaches of the Romans.

Objects and uses of both.

The use of mines seems to have originated in the extreme difficulty and labour which were experienced by besiegers, either in battering down the massive walls of a fortress, or in raising their *aggeres* to a level with the towering battlements. It was by stratagem that the assailants first hoped for success, therefore, when they frequently commenced their subterraneous galleries at a prodigious distance in the country, and, passing under the foundations of the rampart, issued unexpectedly to the surface in the heart of the place. But the besieged, as we have seen, soon learned the art of listening to the approach of the enemy's miners, and of defeating his object. They closely watched the point at which he was about to make his narrow issue, and anticipated his assault by throwing in a shower of stones, or other missiles, and combustible preparations, which at once filled up his gallery, while it repulsed or suffocated his miners and troops. But mining was also more actively employed in the defence, and appears to have been rendered altogether available to a greater degree against the besiegers, than by them in assisting the progress of their attack. By driving out subterraneous galleries or countermines from the walls, the garrison not only ascertained the direction in which the enemy's miners were approaching, and intercepted their advance, but were enabled to diverge to those points above which the *aggeres*, battering rams, and towers of the besiegers, were placed, and to effect their destruction. Such was the twofold object in the example to which we have referred, of the system of countermines constructed in preparation for the defence of Gamala by Josephus. When the garrison of a place attacked had driven their galleries under the besiegers' works, they excavated large chambers supported by timbers, filled them with other combustible matter, and set the whole on fire. The effect of the conflagration, by causing the superincumbent mass of earth to fall in, seldom failed both to sink the movable towers and *aggeres*, and to consume all the com-

* Lib. x. c. 22.

† *De Bello Jud.* lib. iv. c. 1.

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bustible materials of the various machines and constructions of the assailants: while detachments of the garrison, in readiness for the event, sallied from the gates, and availed themselves of the confusion of the besiegers to assist and complete the work of destruction. But sometimes the design of both parties was mutually anticipated and prevented by the meeting of their artificers in these subterranean labours; as happened at the siege of Syrinx, in Hyrcania, by Antiochus, where the opposing miners encountered each other under ground, and fought with great fury.*

Engines of attack and defence.

Of the engines and machines of attack and defence employed in the ancient sieges, the number and variety are too great for detailed description within our limits; and we have already made some mention of them under the head ARTILLERY in our *Miscellaneous Division:* but it will answer every general purpose to mention in this place a few of those most important in their operation, and most common in their use. Nor, as we have already hinted, in our ignorance of many particulars in their form and construction, can more be safely attempted in any modern Treatise, than to notice their purposes and recorded effects. Of projectile engines, the principal were the *catapultæ* and *balistæ:*—terms which have been confused in the application, not less by the ancient Writers themselves than their modern commentators.† Upon the whole, it is most probable that the two words were applied with little fastidiousness, and almost indifferently, for the projectile engines of either kind. But, in any case, the question of names is of little moment; since it is certain that, of the two engines, one was used for the projection both of large stones or masses of work, and of darts or even sharpened beams, and the other of the latter missiles only. The one, worked by a cord, being composed in general of one or more wooden limbs, which on release from tension struck with prodigious violence against a capsill, and threw the projectile by the blow; the other, though often of immense size and power, acting upon the common principle of the arbalest or cross-bow. The twisted cords used in both kinds of engine were frequently composed both of the sinews of animals and of woman's hair; and this dry

Catapultæ and *balistæ*

detail of mechanism will recall to the mind of the Classical reader the interesting circumstance of the sacrifice of their tresses, which the heroines of Carthage made to the public defence in the last struggle of their ill-fated Commonweath. Some of the engines invented by Archimedes for the defence of Syracuse, which deserve notice in this place, varied from these ordinary projectile machines, and consisted in revolving cranes placed on the walls, from whose projecting arms heavy masses of stone and lead were let fall on the galleys of the enemy. Another contrivance of the same master-mind was to employ long levers, having at their outer extremities chains and grappling irons; which, being swung out, caught hold of the men, or even of the vessels themselves; and the latter being drawn partly out of the water by depressing the opposite end of the lever, were suddenly let fall, and either upset or sunk.*

Power of these machines.

The enormous weight and effect of the masses of rock thrown by the larger engines, and the immense number of these projectile machines which were employed in sieges of importance, are features in the ancient attack and defence of places, to excite our surprise and curiosity. Archimedes, if the relation of the siege of Syracuse may be credited, made them capable of throwing weights of ten talents, or eight hundred pounds.† At Ategua,‡ a shot from a *balista* used by Cæsar's troops, threw down a tower, with five of the garrison and a boy, or slave, who served as a sentinel to give notice of the distending of the machine. Josephus makes repeated mention of a similar power of destruction in the larger engines which were employed in Vespasian's sieges in Judæa. At the siege of Cremona§ the garrison from their ramparts upset a machine itself upon the assailants below: it crushed every thing beneath it by its vast weight and size, but dragged a part of the wall after it in its fall, and formed a breach for the besiegers. The confined range, however, of these mighty projectile engines, when placed in competition with that of our ordnance, will be heard with a smile by the modern artillerist. The largest used by Titus before Jerusalem could cast a mass of rock only two stadia, or about two hundred yards:‖ though Athenæus speaks of smaller ones which would carry an arrow half a mile.

Immense number used.

Of the immense number of these engines which were provided in every strong place, there are perpetual proofs. At Marseilles, Cæsar speaks of the *tanta multitudo tormentorum*, with which the arsenal of that city was stored. At the siege of Jotapata, Vespasian had an artillery of one hundred and sixty engines;¶ at that of Jerusalem, Titus employed three hundred *balistæ* and forty *catapultæ*, the smallest of which could throw a stone of eighty pounds.** When Scipio captured New Carthage,†† he found in the place one hundred and twenty *catapultæ* of the largest size, and two hundred and eighty-one lesser; twenty-three great *balistæ*, and fifty-two small; and an immense quantity of scorpions, or simple cross-bow engines, for the discharge of arrows: and when the Carthaginians before the last Punic War surrendered their arms to the mercy of the Romans, above two thousand engines of all kinds for casting

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* Polybius, lib. ix.

† Folard, who has devoted a chapter (vol. ii. p. 312—323.) to this subject, and insists that the *catapulta* was the machine for throwing stones, is probably, in the strict acceptation, right. His opinion is supported in general by the text of Cæsar, Vegetius, and Ammianus Marcellinus, and by the fair inference of etymological derivation; while the only great ancient authority against him is Vitruvius, an authority still far inferior to Cæsar. In the *Commentaries (De Bello Civili*, lib. ii. at the opening) it is said, that the Marseillois shot spear-pointed beams twelve feet long from their largest *balistæ—maximis balistis missi*; and, further on, more expressly, that stones were thrown from the *catapultæ*,—*saxa ex catapultis lateritium discuterent.* Vegetius (lib. iv c. 21.) distinguishes the *balista* as throwing darts, and the *onager*, or wild ass, (a name which appears to have superseded that of *catapulta* for the same engine,) as casting stones. *Balista spicula emittit, onager dirigit lapides.* The Greek derivation of both terms should seem to settle the question. *Balista*, from Βάλλω, *jaculor*, certainly describes the point-blank shot of the dart or *jaculum*: *catapulta* from κατὰ, *circa*, *et* πάλλω, *vibro*, the swinging hurl of the stone. The former might discharge its missile through an embrasure, like the modern cannon; the latter could be used only with a vertical range over a parapet, like our mortars. Yet, on the other hand, Vitruvius (lib. x.) pointedly reverses the terms of the two engines; and it must be confessed, that Hirtius, the continuator of Cæsar, (*De Bello Hispan.*) distinctly calls an engine, which destroyed a tower by the discharge of a mass of rock, a *balista.* This, and the vague disagreement of ancient Writers, may beget a strong suspicion that the words were often used indifferently for either projectile engine.

* Polybius, lib. viii.

† *Idem. ibid.*

‡ *De Bello Hisp.*

§ Tacitus, *Hist.* lib. iii.

‖ Josephus, lib. v. c. 18.

¶ *Idem*, lib. iii. c. 7.

** *Idem*, lib. i. c. 6.

†† Livy, lib. xxvi. c. 47.

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stones and darts, were delivered up from the arsenals of the city.

Aries, or battering ram.

The common purpose of all these engines in attack was to destroy the tops of the parapets, to kill and wound the men behind them, and generally to ruin the defences of the place, and by rendering them untenable to drive from the ramparts the troops of the garrison, whose missiles would otherwise annoy the workmen, and impede the progress of the approaches. To form a breach in the body of the rampart, through which the assailants might enter by storm, was left to the operation of another well-known engine of prodigious power:—the *aries*, or battering-ram. This was a huge beam, pointed horizontally, with a head of brass or iron: sometimes shaped like that of the animal from whose manner of striking it derived its name. In the rudest form of the invention,* it was probably only a transverse beam, balanced from a mast which was set up before the ramparts, and swung against them with its point forward by a number of men, until its repeated blows shook and brought down the wall. But, at least as early as the Age immediately preceding that of Alexander,† contrivances were adopted for enclosing the ram in a movable shed, and thus advancing it to the walls under cover. The whole engine so composed acquired the name of the *ram-tortoise*, which Vegetius derives from its resemblance "to a tortoise with its head poked out of its shell." The shed was usually constructed, like all the movable galleries and towers of attack, of timber covered with the hides of bullocks and other animals: it moved upon wheels or trucks, and had often upper stories for missile machines. In this shed, the ram itself was sometimes worked to and fro, upon a number of trucks in a groove, to give its blows; but it was more frequently suspended by ropes or chains from the roof, and its head thus violently swung against the wall with repeated concussions, until it beat down the mass of the rampart.

Ram-tortoise.

Helepoles, or movable towers.

Of the great movable towers, or *helepoles*, in common use at sieges from the Age of Alexander, the accounts transmitted to us are, unlike those of many other machines, perfectly intelligible. But the stupendous height which was given to them, the immense labour and quantity of materials required for their construction, and the difficulty of moving forward such towering and unwieldy masses, are among the most extraordinary circumstances of ancient warfare, and would be absolutely incredible, if their constant use and proportions were not too well authenticated for doubt. They were generally of ten stories or more, and above a hundred feet high; and Vitruvius,‡ on the authority of Diades, a famous engineer in Alexander's wars, recommends that the breadth of their base should be from seventeen to twenty-three cubits, and their height from sixty to one hundred and twenty cubits, and that every tower should be gradually narrowed at the top to four-fifths of its base. The *helepolis* moved upon four, six, or eight broad oaken trucks, and it was composed of timber,§ covered with raw hides, as we have already observed, to protect it from fire. The uses of these towers were obvious: whether placed on the natural plain or on the *agger*, to gain the advantage of height, and overlook the walls; to drive the enemy from their defences by showers of missiles from the machines in the different stages and on the summit; and, finally, when the tower had been rolled close to the rampart, either to enable the ram to work against it from the lowest floor, or to afford a passage for the assailants to the wall from the top, by means of a drawbridge, prepared for that purpose, and let down upon the battlements of the place.

Their stupendous height and dimensions.

Various smaller engines.

Of the smaller movable sheds of attack, since they were constructed much on the same principle, we have neither space nor occasion to give any lengthened description. Such were the *pluteus*, the *musculus*, the *testudo* of approach, all covered buildings of carpentry, hides, hurdles, &c. pushed forward on trucks, for levelling the ground in front of the heavier *helepoles* and ram-tortoises, for covering the various works of approach, for filling up the moat of the place, and for undermining the walls. Neither is it necessary to load our pages with an account of the various machines for escalade, cranes for raising the assailants to the battlements, (especially from the galleys in maritime sieges,) and the thousand other expedients which the martial ingenuity of the Ancients dictated under as many varying circumstances; and which are to be found in all the old professional Treatises.

General course of attack,

From the particulars into which we have already entered respecting the machines and constructions employed in the Grecian and Roman practice, the general reader will already have acquired a sufficient insight into the scientific process of an ancient siege. He will have observed that the primary object of the besieger was to approach the walls of the place under cover, and with the least possible sacrifice of life to his troops. With this view were employed either: 1st, subterranean galleries to arrive at the foundations of the ramparts; 2dly, covered galleries and communications of approach, such as *vineæ* whether raised blinds or trenches, and movable sheds, and towers; 3dly, *aggeres*, or mounds rising to the height of the battlements, and pushed to the edge of the ditch, or even filling it; 4thly, missile engines of all kinds to ruin the defences, to overpower the discharges of the garrison, and to drive them from the ramparts. This primary object of touching the walls having been effected, the ultimate process was either to bring down the rampart, and form a breach for passing into the place, by the mine or by the strokes of the battering ram; or else to pass over it by drawbridges from the *helepoles* and *aggeres*, and pour columns of troops into the place.

and of defence.

On the other hand, it was the object of the besieged to impede the progress of the enemy by destroying or rendering useless their works, and overpowering their workmen with missiles. For this end, they employed the greatest possible number of projectile engines on their towers and walls, and kept up an incessant discharge upon the approaches; they hurled down all kinds of heavy masses from the walls to crush the sheds of the assailants below; they attempted frequent sallies to fire the towers, sheds, *vineæ*, engines, and *aggeres*, for which the combustible nature of the timber and faggots, and other materials which were necessarily used, both in the wooden buildings and accumulated mounds of the besiegers, gave great facility; and the labour of weeks and months was thus frequently destroyed in as many hours. On their walls, the garrison protected themselves from the missiles of the

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* Vitruvius, lib. x. c. 19.

† *Idem.*

‡ *Ubi suprà.*

§ Cæsar's tower of brick at the siege of Marseilles is a famous example of another kind. But though constructed under the range of the missiles of the garrison, it was rather a lofty redoubt for defence against sallies than a tower of attack, and was, of course, not movable.

assailant, by the same contrivances of wooden blinds, hurdles, hides, &c., which he used. To the successful employment of countermines for sinking *aggeres* and overturning the *helepoles* we have already adverted: but there were sometimes even simpler modes of arresting the approach of those unwieldy masses of timber, of which a single example, related by Vitruvius,* may suffice. At the siege of Rhodes, Demetrius, one of the most able of the martial successors of Alexander, who had acquired the surname of Poliorcetes, (besieger of cities,) from the number and success of his enterprises, constructed an enormous *helepolis*, one hundred and twenty-five feet high and sixty broad, and so secured with hair-cloth and raw hides, that it could stand the blow of a stone weighing three hundred and sixty pounds from an engine, and was probably indestructible by fire. This huge tower itself is said to have weighed three hundred and sixty thousand pounds; and its approach threatened imminent peril to the besieged. Yet merely by inundating in the night the soil over which it was to pass with quantities of water, mud, and filth, the citizens produced such a quagmire, that the dreaded machine stuck fast and sank by its own weight, so that it could be moved neither forward nor backward; and Demetrius was compelled there to abandon it, and to raise the siege! The most formidable engine, when its advance to the walls was once effected, seems to have been the ram: yet the besieged were not without the expedient of strengthening their rampart against its shocks, to an immense mass and thickness at the points most exposed to attack; and sometimes mattresses of wool and hair-cloths were hung over the walls to deaden the blows of this battering machine. Another frequent contrivance was to noose the ram by a chain or cord dropped from a crane upon the rampart, and by this means to raise the head of the beam in the air, while fire, the great auxiliary of the defence, was showered in every form upon the tower or shed.

Superiority of the ancient Art of Defence to that of Attack.

Altogether, therefore, as will be concluded, the Art of Defence in Ancient Fortification had an infinite advantage over that of Attack; and it was only by immense numerical superiority and mechanical means, by unwearied labour, and indefatigable patience and activity, that the assailant, advancing on his feeble lines and heads of attack, could approach the defences, and effect a passage through the ramparts of a well-fortified place. For once in the History of mankind the Art of fortifying had nearly perfected its professed object; and apart from the ravages of famine and pestilence, and the bane of domestic treason and dissension, every strong place, if well-garrisoned, and defended with as much skill and courage as it was assailed, may almost be pronounced to have been impregnable. Nor were there wanting, in the ferocious principles of ancient warfare, strong motives of human passion to increase the moral energies of a besieged population. While, from behind their lofty and solid ramparts, with plenteous stores of provision and a well-filled arsenal, a brave and united people might securely defy the assaults of a besieger, the dreadful consequences of surrender or defeat were far more appalling than the ordinary privations of a siege. For the best fate they might expect from the mercy of the conqueror was slavery in its bitterest forms: the sure consequences of capture by assault were death by the sword to themselves, and worse than that death to their women and children. In our ordinary modern warfare, in which a garrison may safely resist behind their last intrenchment with the certain power of an honourable capitulation, it is impossible for us to conceive the agony of patriotism and desperation, by which the defenders of an ancient city were wrought to superhuman endurance. The whole siege was in truth a death-struggle of ferocity and terror, not a mere effort of martial emulation. Even the horrors of a modern assault in their rare and unmitigated excess, fall more cruelly upon the often neutral and passive inhabitants of a city than upon the troops of the garrison, to whom quarter is seldom denied. The modern soldier resists or surrenders, with equal indifference to the lot of a population to whom he is bound by no ties of affection: but the ancient warrior beheld all that was dearer than life involved in his own ruin; and in anticipation of the sanguinary and brutal triumph of the victor, might well shudder, not at the death which he probably welcomed, but for the slaughter, the violation, and the servitude, which his own fall would prepare for his miserable kindred.

Aided by the despair of the besieged.

Consequences of defeat or surrender.

* Lib. x. c. 22.

CHAPTER II.

Fortifications of the Middle Ages.

Long continuance of the ancient mode of fortifying.

We have abundant evidence from the Histories of the Sieges which have taken place in Europe and Asia, that the nature of the military engines used in the attack and defence of fortresses underwent no material change, from the days of Cæsar till the discovery of gunpowder; and it is known that the ancient *balistæ*, *catapultæ*, &c. continued to be employed in conjunction with cannon for a considerable time after the latter were mounted on ramparts or brought into the field. We may, therefore, reasonably conclude that, during all this long period, the manner of fortifying towns and military positions remained the same as that described in the Works of Vitruvius, who is believed to have lived in the time either of Augustus or of Vespasian: but the employment of the modern artillery, small indeed at first, and far less important in its effects than that which is used at the present day, at length rendered it necessary to exchange the lofty stone walls of the Ancients for ramparts of earth, which were soon found more efficacious in resisting the shock of this powerful arm.

Earthen ramparts, why not sooner employed.

It may, at first sight, seem remarkable that such ramparts were not frequently constructed even while the ancient engines were in use: since it is evident that the material which is best capable of resisting the momentum of an iron ball, must also have been best capable of resisting that of a battering-ram; and it would seem to have been impossible, supposing the parapet formed as at present, with its exterior face at an angle of forty-five degrees with the horizon, to bring such machines as the *helepoles* near enough to permit the assailants to pass into the fortress by a bridge, thrown upon the parapet from the top of the machine. Ramparts constructed merely of earth are certainly mentioned by the Ancient Writers as the fortifications of towns and military posts: but, except where they served as lines to protect a country from the inroads of Barbarians,—like the walls of Hadrian and Antoninus in Britain, and the chain of redoubts constructed along the Illyrian frontier in the latter Ages of the Roman Empire,—such appear to have existed only among rude

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nations and in situations of small importance. That elevations of earth were sometimes formed for the protection of the ordinary brick or stone ramparts is, however, rendered probable by the fact, that there remained, in the XVIth Century, in the ditches of some ancient fortresses, a bank of earth parallel to the sides of the fosse, but separated from both, and covering the inner wall of the excavation as far up as about three-quarters of its height. It is asserted by Maggi,* that such banks in his time existed in front of the old circuit of wall at Calais, and at another place in Flanders; and he adds, that at Pisa, banks of the same nature were placed close against the walls of the curtains for the purpose, he supposes, of resisting the engines brought against them by the besiegers.

Facilities afforded by such works to escalade.

But in ancient warfare the practice of engaging in combat hand to hand was so general, and personal prowess and self-devotion were held in such estimation, that when an attack by storm was possible, it was always preferred to a slower but more secure process: the sacrifice of life entailed by an open assault being then less regarded, than that of the time which would be incurred by forming a regular siege. It being such assaults, therefore, that the defenders would chiefly apprehend, it may be conceived that ramparts similar to those of modern construction would be thought to offer too many facilities to an escalade; and this, together with the opinion that they would be more easily undermined, may account for the preference given to ramparts of stone or brick. While, therefore, the penetration of the rampart at its foot was to be feared, thick stone walls remained necessary: in order that a sufficient resistance might be opposed to the enemy's miners. And, while the walls were liable to be passed by escalade, it was essential that they should be lofty, in order to augment the difficulty of the assault. In fact, the heights of the walls and of the opposing turrets of the besiegers seem, in emulation of each other, to have gone on increasing during all the time that the old system of attack and defence continued: but a great thickness of wall was only required near the foot; and this was accomplished by raising a mass of earth there, either on the interior or exterior. In the parts of the wall above the place where the ram might come in contact with it, it was sufficient to have the thickness adequate to resist the stones or other missiles thrown from the machines: consequently, the loop-holed galleries therein made, to serve for communications and as stations for the archers, became admissible, and did not diminish too much the strength of the rampart.

Proofs of the unvaried character of the Art of Fortification in the Classical and Middle Ages.

To mention only a few circumstances in support of what has been asserted concerning the unvaried character of the Art of Fortification during the period abovementioned, we may observe that, in the IId Century of our Era, the City of Byzantium, which was then considered impregnable, and which, during three years, resisted all the power of Severus, and all the means employed in the ancient mode of attack, was fortified, as were all other Cities of the preceding Ages, with walls and towers of masonry.† In the same style also, after their subsequent destruction, those walls were rebuilt; and when besieged by Constantine, the attack and defence are described as being conducted in the accustomed manner. The assailants raised an *agger* or mound, of equal height with the walls of the place; surmounted this huge elevation with lofty *helepoles* and projectile engines; and finally breached the walls by the ram.* So also, when the City became the seat of the Eastern Empire, the new fortifications were of the same kind as the former: the extent of the walls and the number only of towers being augmented.† Of the latter, it is said, that, in the reign of Theodosius, fifty-eight were overthrown by an earthquake, and subsequently restored.‡

A. D. 323.

Evidence of Procopius.

We may collect from the Works of Procopius§ that the military architecture of the VIth Century differed in no respect from that of preceding Ages: for, in describing the fortifications constructed about Dara in Mesopotamia, during the reign of Justinian, that Writer states that the City was surrounded, at the distance of fifty paces from each other, by two walls, which were strengthened by towers: that the inner wall was sixty feet high, and the towers one hundred feet; and that besides the platforms at the top of the walls and towers, on which the defenders were to be stationed, there were galleries formed in the thickness of the former. He observes that the exterior wall was less lofty; and that against the back of the towers were raised large elevations of earth to serve as places of arms for the defenders at the time of an assault. The whole was surrounded by a double ditch; and the entrance was protected by an outwork of a semicircular form.‖

State of the Art between the IXth and XIIth Centuries.

If we pass over the dark interval between the IXth and XIIth Centuries, we shall find that, at the latter epoch, the fortifications of Cities had been maintained in all their former strength; but that no improvement had been made in the nature or dispositions of the works, nor in the modes of attack and defence. On the contrary, it may be gathered, from the relation of the sieges undertaken in the First Crusade, that the state of martial Science, in this as in all its other branches, had retrograded since the Ages of Classical Antiquity. Thus, as we have seen, in another portion of our Work,¶ Nice, when invested by the Crusaders, was surrounded by double walls of stupendous height and thickness, provided with a deep ditch, and flanked at intervals by no fewer than 370 towers. The attack of the City was carried on by means of lofty wooden towers, the *helepoles* of the Ancients, now termed *belfredi*, or *belfrois*;** by covered galleries and movable sheds, the *pluteus*, *musculus*, &c. of old, now called indifferently foxes and cats, or *chat-chateils* when surmounted by a tower; by battering rams contained within all these structures; and, lastly, by all the balistic engines of earlier Ages. But the whole of the towers and galleries of attack were burned by the Greek fire of the besieged; and it was not until after much mismanagement and loss, that the Crusaders, by the aid of an Italian engineer, succeeded in attaching a *chat-chateil* to the walls of the City. From that machine, undermining the foundations of a tower, which had been injured in a former siege and leaned forward from its base, while they supported the superincumbent mass on strong wooden props, they finally, by firing these timbers, brought down the whole structure

Sieges in the Ist Crusade. A. D. 1097.

* *Della Fortificatione delle Città*, lib. ii. c. 24.
† Dion Cassius, lib. lxxv.

* Zosimus, lib. ii. p. 97, 98.
† Codinus, *Antiquitates Constant.* p. 12.
‡ Du Cange, *Constant.* lib. i. c. 10, 11.
§ *De Edificiis*, lib. ii. iii.
‖ Procopius, *De Edificiis*, lib. ii. c. 1—3. &c.
¶ Vide our *Historical Division*, ch. lxxii. p. 599
** Du Cange, v. *Belfredus*.

Fortification.

A. D. 1099.

at a single crash, and displayed a yawning breach. Two years afterwards, Jerusalem was besieged and defended in a similar manner: after the destruction of various other engines of assault by fire, the besiegers could advance only one movable tower to the walls at a point at which the fortifications were low and the ditch deep. The latter was filled up; a *barbacan* or outwork was beaten down; the tower was rolled up to the inner wall; its drawbridge was let down upon the rampart; and the troops rushing over the battlements obtained possession of the City.*

Examples of the unchanged state of the Art in the Italian wars of the XIIth and XIIIth Centuries.

The Histories of the wars in Italy, and particularly the relations which have been transmitted to us of the sieges of Como, Tortona, and Cremona, show that the towns in that part of Europe, during the XIIth and XIIIth Centuries, were fortified and attacked in the ancient manner. The first of these places seems to have been strengthened by castles in the nature of advanced works: for the Milanese, who besieged it, are said to have passed them without attack; and encamping under the walls of the city, they caused to be erected four great towers covered with hides, which were wheeled up to the walls. From these the cross-bow men, stationed on their tops, annoyed the defenders; and between them were placed what are called *gatti*, or cats: a sort of battering ram having at the end an iron hook to tear out the stones which were loosened by the shock. *Balistæ* also were used for throwing pieces of rock against the walls.† In a manner precisely similar were the two other places above mentioned attacked by Frederic Barbarossa; nor do we find any other difference, except such as arose from local circumstances, in the nature of the attack on Constantinople when it was taken by the Latins in the IVth Crusade.

And in the siege of Constantinople. A. D. 1203.

It is stated that the towers of the City on the land side were raised above their ordinary height by several stages of wooden turrets, in order to command the machines of the enemy; and that the Venetians having disposed their fleet along the wall, on the side next to the port, swept that wall with arrows and stones discharged by men stationed on the masts of the ships. This division of the army on landing is said to have taken as many as twenty-five towers;‡ a proof of their vicinity to each other, and that they did not exceed the usual size of such works.

Influence of the Feudal System upon the construction of fortresses.

The rise of the Feudal System, however, during the Dark Ages had produced a description of fortress in the Western Kingdoms of Europe, which, while constructed with embattled walls and towers according to the ancient system, exhibited several new and peculiar features. These were suggested by the nature of the site, and the purposes which distinguished such strong-holds from large and populous cities. The anarchical state of Society, and the frequency of private wars among the Feudal Nobility, bestowed a license and imposed a necessity upon every Chieftain to fortify his house. While the dwelling itself of the lord and his family was strongly constructed in the form of a tower, and rendered capable of defence by a small body of domestic retainers, against any sudden attack, a larger space, sufficient for the refuge of his numerous vassals with their effects, and for the endurance of a regular siege, was obtained by surrounding the main building with a single or even double circuit of walls. The rural fortresses which, as we are informed by Procopius, were plentifully provided in the frontier Provinces of the Eastern Empire under the reign of Justinian, afford an earlier example of the same kind of works: since they consisted of a stone or brick tower, in the midst of an area surrounded by a wall and ditch, to which the neighbouring peasantry might retire with their cattle for protection against the inroads of the Barbarians. But the castles of the Feudal Nobility throughout the Dark Ages were continually enlarged in extent and increased in strength, until they were made capable of containing powerful garrisons, and rendered almost impregnable against the ordinary modes of assault.

Description of a Feudal Castle.

Although the license of private war was more severely restrained in England than in the Continental States of Europe, a very complete idea may be formed of the castles erected by the Feudal Nobility from the existing remains of such structures in our own Country. These show that the residence of the proprietor was a large building, generally rectangular, of great height, and strengthened at the angles by turrets, in one or more of which were the winding steps leading to the several floors, of which there were sometimes four or five, and to the upper platform of the edifice. Underneath were dungeons in which the captives taken in the field, and often the victims of lawless power, were confined; and frequently subterranean galleries, commencing under this building, were carried far beyond the outer walls, to facilitate escape in the event of the castle being taken. Near this edifice were commonly situated the chapel, stables, and the domestic offices; the whole were surrounded by embattled walls which were sometimes double; and the name of the inner and outer *ballium* was given to the areas which those walls respectively enclosed. The periphery of the walls was generally irregular and adapted to the nature of the ground; at intervals were placed towers of a square or circular form as in other ancient fortifications; and these, though used for the purposes of defence, served also as magazines, or dwelling-houses for the principal officers belonging to the castle.

When the walls crowned the summit of a rock, no ditch was necessary, but when the surrounding ground permitted the works to be accessible, the whole was surrounded by a broad and deep *fosse*. The grand entrance was flanked by embattled towers, closed by massive gates, and protected by machicolations and a *portcullis* or close grating of iron, which was drawn up and let down by grooves prepared in the stone work. The ditch was crossed by a drawbridge, which, in time of danger, was raised, to prevent any one from entering within the walls; and the bridge was frequently covered by an exterior work, called a *barbacan*, consisting generally of a stone wall built in the form of a portion of a circle, or polygon, strengthened at intervals by towers and protected by its own ditch and drawbridge. Within the outer wall there has been frequently observed a mound of earth, and this is supposed to have been a sort of *cavalier* (as such raised batteries are called in modern fortification), on which engines were placed to oppose those of the enemy. The central building generally served as a *keep*, or citadel, which might hold out for some time after the walls of the castle were taken; but when some great elevation of the ground rendered the spot difficult of access, the keep was formed on the periphery of the inner or outer wall. The ascent to it from the *ballium* was by narrow steps; and deep

* Vide our *Historical Division*, ch. lxxii. p. 610.

† *De Bello Comensi*, apud Muratori *Script. Ital.* vol. v. p. 452, &c.

‡ Villehardouin, c. 93. p. 29.

Fortification. wells were dug within to supply the garrison with water.*

Mode of besieging such fortresses. In the siege of such fortresses, since the range of the warlike machines then in use was not great, the assailants sometimes began their operations with the attack of the outer wall, which frequently consisted only of a row of strong palisades, and was then denominated the *lists.* Many feats of Chivalry were here performed by the Knights and men at arms, who considered the assault of that work as particularly belonging to them; the weight of their armour preventing them from scaling the walls. The besiegers having carried the lists, brought up their machines, and established themselves on the outer edge of the ditch, which, under cover of their tortoises, they began to fill with *fascines* or faggots: over this surface were impelled the movable towers, from which the cross-bowmen annoyed the defenders; darts and stones were thrown from the engines; and the walls were either battered by the ram or undermined. The smallness of the range of missiles from the ancient engines rendered it no disadvantage to the works to be commanded at the distance of four or five hundred yards; and such was actually the case with the Castle of Dover, which was once considered as the key of the Kingdom.† Fortifications of the kind which we have been describing yet remain in different parts of the Continent of Europe, situated on rugged and often inaccessible rocks, showing their ruined battlements and towers from a great distance; and recalling to the mind of the traveller those tales of chivalric exploits, of which the relation has so often charmed his youth.

Invention of gunpowder. It must have been in the wars which devastated the North of Italy in the beginning of the XIVth Century, and probably between the death of the Emperor Henry VII. and the election of Louis of Bavaria, that the invention of gunpowder, which was subsequently to produce so great a change in military operations, took place. But whatever may be the precise date of its discovery, it appears to have been first used in the field by the Venetians, in A. D. 1330. Before the XIth Century the Italians, from their frequent intestine wars, had made themselves skilful in the art of attacking and defending places; and Pisan and Genoese engineers seem to have had the direction of all the sieges carried on by the Crusaders against the cities of the East. We find them also employed in the erection of fortresses in Flanders so late as the time of Charles V. It is not, therefore, wonderful that a people thus exercised in martial science and practice should have been the first to adopt an invention, which promised to render victory an attendant on every movement of their armies.* But

Slow progress of the changes which it produced in the Science of Fortification. the discovery of gunpowder does not seem to have produced at once the change that might have been expected in the construction of fortresses; nor to have given complete success on every occasion of its employment in the attack of those already existing. In fact, however, the first guns, except in a few cases, were so little superior in effect to the rams and *balistæ* of the Ancients, that the latter were long used in conjunction with them for every military purpose to which either was applicable.

Example in the last siege of Constantinople. A. D. 1453. The most remarkable instance of such an admixture occurs in that fatally memorable siege which, in A. D. 1453, gave the last City of the Romans to the power of a Turkish Sultan. The fortifications on the land side of Constantinople consisted of a double wall, with a ditch in front one hundred feet deep, and extending to the length of four miles. Against this wall and its towers, were raised fourteen batteries of guns, among which were three pieces said to be capable of throwing stones weighing from six hundred to twelve hundred pounds. But, with these, we read that there were engines for throwing darts, and rams for battering the walls: as if the effect produced by the guns was not sufficiently great; or as if the breaches which they made were too steep to be ascended. The ditch being at length filled, a movable turret was advanced on rollers up to the wall, where, however, it was destroyed by the fires of the besieged. The guns of the Greeks are said to have been of small calibre, the weakness or want of breadth of the ramparts not permitting a heavy artillery to be used upon them.*

This, however, is not the earliest instance in which the ancient and modern artillery were combined: for when, in A. D. 1383, the Bishop of Norwich besieged Ypres, the garrison is said, by Walsingham, to have defended itself so well with stones, arrows, lances, Greek fire, and guns, that they obliged the English to raise the siege, and leave behind them all their artillery.†

* Grose, *Milit. Antiq.* vol. ii. p. 336, 337, &c.

† Grose, *ubi suprà.*

CHAPTER III.

Rise of the Bastion System.

The transition to a new style of fortifying almost imperceptible. In almost every Science and Art the progress of improvement has been so gradual, that the difference between two consecutive states has, for the most part, been too small, to admit precise observation of the epoch at which any particular improvement took place. It ought not, therefore, to be a matter of surprise that, in Military History, no trace should be found of the transition from the ancient walls and towers, to that form and disposition of the works which the use of artillery rendered necessary. But the absence of all notice of any novelty in Fortification between the Greek or Roman style and that which is known to have been followed in the XVIth Century, may, perhaps, be considered in itself as a proof that the works of that Age were those which immediately succeeded the constructions belonging to the Ancient School. It is more than probable, indeed, that, for many years after the invention of gunpowder, no entirely new fortifications were erected, but that, on the accessible fronts of towns, the thickness of the ancient ramparts was increased, in order that they might be better able to resist the shock of a more powerful artillery. At the same time the great height of the walls, which until then had constituted their principal advantage, became a serious defect: for being thus exposed to the view of the enemy, they were breached after a few hours' firing from guns planted even at a considerable distance from the works. It was, therefore, soon found necessary to lower the walls and cover them by parapets of earth constructed in front; and in order to secure them against the attempts of the enemy to carry them by escalade, the depth of the ditch was proportionally augmented: but with

* See Gibbon, *Decline and Fall, &c.* c. lxviii: who in that splendid narration of the capture of Constantinople by the Turks, has not failed, with his usual acuteness, to remark the admixture of the ancient and modern artillery and expedients of attack as a distinguishing feature in that memorable siege.

† Walsingham p. 303, 304.

these exceptions, the other parts of the same fortress remained unchanged. From the description given of the siege of Metz, in A. D. 1552, it appears that the fortifications of that city then consisted of a single wall with square and round towers; and that to put it in a state of defence, the Duc de Guise, who commanded, raised cavaliers, or mounds of earth on the exterior for cannon, with parapets formed of large gabions: he also thickened the walls inwardly by the same means, and within their periphery he formed retrenchments of earth strong enough to resist the guns of the enemy, who had breached the exterior wall in several places.

Construction of angular and flanking towers, The destruction of the machicolated parapets by the guns of the besiegers at an early period of the siege, by depriving the defenders of the cover behind which they used to annoy the enemy when he was at the foot of the wall, evidently rendered it necessary that the faces of the towers should be seen and defended by fires directed from some other part of the works; and, for this purpose, the engineers of the day replaced the old round towers by others with plane faces, presenting an angle to the front. It is alleged, indeed, that a construction of this kind had been occasionally employed by the Ancients; and that some of the towers of Jerusalem, as well as many of those about the castles of the Nobility of a former Age, were of an octangular form on the plan.* But, let this have been as it may, the necessity for such flanking towers now became evident; and from within half a Century, probably, after the first introduction of cannon in the field, we may date the general practice of constructing such works at the angles of the polygonal wall surrounding a fortified place. A tower consisting frequently of two faces forming a salient angle, and of two flanks, but sometimes having a greater number of faces, and situated as we have described, but of dimensions hardly exceeding those of the Roman times, was called *balvardo:* a name derived by Maggi† **or balvardi.** from *bellunguardo*, signifying that which constitutes the strength or maintenance of battle. It is observed also by the same Writer that, from the acute angle formed by the two faces, the towers had the name of *puntoni*, (probably from their resemblance to the pointed head of a spear or other weapon,) and he adds, from the information of Marco Manini, whom he qualifies with the character of a diligent observer of the things of his time, that they had been so called for seventy years before; which, as his Work was written in A. D. 1584, carries the invention of this species of tower so far back, at least, as the commencement of the XVIth Century.‡

Provisions for their defence from the curtain or connecting line of wall. The same writer alleges, that the curtain or connecting line of wall between the towers, was at first made straight, and served for the defence of the *balvardi* or *puntoni*, in which, he observes, consists the safety of the city: but he goes on to say that, since nothing can be made by Art which by Art may not be destroyed, the *shoulders* of the fortress, as he calls those works, were ruined by the besiegers, and then the curtain was exposed. To remedy this evil, he recommends that the latter should be broken in two parts, forming with each other a reentering angle; and in this way, he observes, the City of Nicosia in Cyprus was, in his time, fortified with eleven *balvardi*, by Giulio Savorgnano. He admits, moreover, that this method of breaking the curtain was not new, but the invention of a preceding Age, and asserts that, in the year 1550, he saw such a curtain in the fortifications of Padua. It is, also, worthy of remark, that Maggi, in describing the advantages of the broken curtain, states that when the enemy would attempt to breach it by a direct fire, he must present an end of his battery to one of the oblique lines of the curtain; from which that battery may consequently be enfiladed. In the plans of fortresses proposed by this Writer, the faces of the *balvardi* are equal to about one-seventh only of the distance between two of those works; the lengths of the flanks are little more than one-twentieth of that distance: and half the flank is taken up with an *orillon*,* evidently intended to cover that part of the work from the view of the enemy: two tiers of guns are placed on the flanks, to fire either over the rampart, or through it from casemates, for the defence of the ditch.

Probable Authors and Era of their improvements. Tartaglia of Brescia, and San Micheli of Verona, who lived only a few years earlier, and were even for some time contemporaries of Maggi, are mentioned as engineers distinguished for the improvements which they introduced in the Military Art. To the former is ascribed the first formation of the *orlo*, or covert-way, surrounding the fortress on the exterior of the ditch, a work the importance of which has been ever since acknowledged; and to the latter, the invention of the *balvardo* itself. This opinion is, however, founded only on a passage in the *Vitæ excellentium Architectorum* of Vasari, which was published at Florence in A. D. 1597, where it is said that, before the time of San Micheli, the *balvardi* were made circular; and Maffei, who, in his *Verona illustrata*, advances that opinion, observes that there are still among the works surrounding that city some towers on which are inscribed the dates A. D. 1523 and 1529, at which times San Micheli is known to have been employed by the Venetian Government in the construction or repair of several fortifications in Italy and the Greek Islands.† But this only shows the probability that such works were then constructed by San Micheli, not that he was the first to construct them. Tartaglia makes mention of *balvardi*, in his *Quesiti ed Inventione diverse*, published at Venice A. D. 1546, as a new invention of great importance. Brantome and Montluc attribute the invention to Antonio Colonna, who was killed at the siege of the castle of Milan. The honour of the invention is even assigned to the Ottoman Commander, Achmet Bassa; who, it is alleged, raised such at Otranto when, A. D. 1480, he made himself master of that City. But it has never been the character of the Turks to make discoveries in Art; and it is more probable that Achmet only caused his engineers to copy the forms of works which might then have been recently introduced.

Numerous fortresses constructed by the Venetians in the XVth and XVIth Centuries. In fact, after the taking of Constantinople, while the wars in Italy rendered additional works necessary in that Country, the apprehension that the Turkish power might still further extend into Europe, induced the Venetians to rebuild and increase the number of their fort-

* It may also be observed that some of the ancient towers of Carisbrooke Castle have the appearance of square buildings placed diagonally with respect to the walls between them.

† Maggi e Castriotto, *Della Fortif. delle Citta*, lib. i. cap. 9.

‡ *Ibid.* cap. 10.

* An *orillon*, or *orillion*, (*Italice orecchione*,) so called from its resemblance to an *ear*, is a prolongation of the face of a *balvardo* or bastion in a semicircular or rectangular shape, beyond the flank, which it thus covers in a retired position from the view of the enemy.

† The bastion *Delle Maddalene* at Verona, which, though small, exactly resembles one of those constructed by Vauban, bears date A. D. 1257

Fortification.

resses in Corfu, Candia, and Cyprus. A time of great political excitement, like that of which we are speaking, by calling into action the powers of the human mind, is favourable for the introduction of novelties; and, to the improvements which then took place in the Sciences and Literature, must be added those made in the Art of Defence, which the new constructions would afford an opportunity to put into execution. To the engineers whom we have above mentioned as living about the time of the great change in the construction of fortifications, we may add, Cataneo, San Marino, and Albert Durer, who were nearly contemporary with each other. No particular systems of works indeed are ascribed to them: but they wrote on the principles of the Art as it existed in their day; and we seem to be indebted to them for the first application of almost every work raised for the defence of a modern fortress. Since those days the most distinguished engineers have been Errard de Bar le Duc, (A. D. 1594,) Marchi, (A. D. 1599,) De Ville, (A. D. 1639,) Pagan; (A. D. 1645;) and in later times, Vauban, Cochorn, and Cormontaingne.

Celebrated engineers of those Ages.

Invention of bastions and ravelins.

The necessity of covering the curtains of masonry which joined the ancient towers, to prevent them from being destroyed by artillery, suggested, soon after the invention of the *balvardo*, the construction of works in earth in front of those curtains. These, which were made like the former, with two faces forming a salient angle, and sometimes with flanks, were well known in the time of Errard* and De Ville; and the invention of them is by the latter ascribed to the Italians.† But it appears that they were first used in that situation subsequently to the time of Castriotto and Maggi, or between the years 1584 and 1594: since the last of these Authors makes no other mention of them than that the bastion of Gatti at Padua, which he designates as a *rivellino*, or ravelin, was a work of that nature.‡ It should seem that, at first, all works of earth, whether constituting part of the fortifications of a town, or of the retrenchments made during the siege, were, in the time of Maggi, denominated *bastioni;* (great buildings;§) and probably it was not till some time after the system of the Italian engineers was adopted by those of France, that the name of bastion was restricted to the work which had been made to replace the *balvardo* at the angles of the polygon surrounding the place fortified. It may be observed, that Maggi never uses the term *bastioni* except when speaking of works made with earth; and that these were sometimes constructed without due care, is proved by a passage in his third book, where it is said that Lucca Martini had built one at Pisa which, for want of bond timbers, gave way on one side from the effects of rain; and that a like accident befell a work constructed with earth at Corfu, by San Micheli. The *rivellino*, or ravelin, whose name is apparently derived from *velletta*, or *vedetta*, a watchman or sentinel, was at first constructed beyond the circuit of the walls; and Errard, in some places, uses indifferently the word bastion and ravelin to designate a work so situated.

The advantage of having capacious works may be said to have been felt almost as soon as the new method of fortifying was introduced; since Maggi complains that the fortresses of his day could not be defended after a breach had been made in the walls; and assigns as a reason the smallness of the places, which would permit no retrenchments to be made in them. He observes, also, that it would be better to lay out money in making the *balvardi* large, the walls high, and the ditches deep, rather than in multiplying the number of the *balvardi:* for if these are too near each other, the defenders are liable to receive injury when the artillery on the walls is fired against the works of the enemy. To increase the defence of fortresses, he says, engineers had invented platforms, cavaliers, and casemates. The first he describes as of two kinds: either small works, resembling the modern bastions, but projecting from the middle of the curtain, and containing on their flanks artillery to defend the faces of the *balvardi* when these were not very distant; or retired spaces in the curtain resembling the second flanks, as they are now called, in Vauban's Third System, and on which, also, artillery was placed for the same purpose. The cavaliers were elevations of earth either on the middle of the curtain or at the back of the *balvardi;* and on these, also, artillery was placed, under cover of *gabions*, or cylindrical baskets of earth, for the purpose of keeping the enemy at a distance by the superiority of their command.

Other new constructions of the same epoch.

Platforms.

Cavaliers.

Lastly, the casemates were recesses in the flanks of the *balvardi;* and, according to Castriotto,* they were sometimes made, in the form of vaulted galleries, across the ditch; but he recommends that they should be built behind the outer edge of the ditch opposite the faces of the *balvardo*, and on each side of its salient angle, their use being, as at present, to defend the ditch when the enemy had entered it. The Italian engineer admits that, if cannon were fired from them, they might become unserviceable on account of the smoke; but he proposes to employ in them only cross-bows and engines for stones; and he alleges that they may be useful for galleries of countermines. The *balvardi* of that day were always made with very short flanks, which were divided into upper and lower stages, each containing only one or two guns, and protected by *orecchioni* or *orillons*, which were generally of a circular form, at the shoulders of the *balvardi.* The guns on the lower flank stood on an open platform, protected by a parapet of masonry with embrasures; behind them was a semicircular wall, having its concavity outwards, which supported the earth constituting the upper flank; and over this wall the guns on the platform of the *balvardi* fired *en barbette*, or over the parapet. Behind this circular wall were sometimes situated casemates, containing guns, which then formed a third battery between the levels of the other two. The walls supporting the ramparts of the place were occasionally strengthened by vertical or horizontal counter-arches. Maggi relates that such works were, in his day, to be seen in several of the cities of Tuscany; and that there was at Padua a strong one, which had been built in A. D. 1550, from a design given by San Micheli of Verona. Under the *gorge* or back of the *balvardo* was a vaulted gallery, the roof of which was supported on pillars, and by which a communication was made from one flank to the other. He observes that this gallery may also serve as a countermine; for, on abandoning the *balvardo*, he would have powder deposited in pits made on purpose under the piers: and these being blown up, there would be left a ditch between the enemy and the town.

Casemates.

Orillons.

Counter-arches and galleries.

* *La Fortification réduite en Art*, liv. iii. ch. v.

† *L'Ingénieur parfait. Avant-propos*, ch. ii.

‡ *Della Fortificatione delle Citta*, lib. iii. c. 25.

§ *Ibid.* c. 20.

* *Della Fortificatione delle Citta*, lib. i. c. 10.

Fortification.

Counterguards.

After speaking of the banks of earth which have been observed in some of the old ditches of fortresses, Castriotto proposes, in order to increase the strength of such places, to connect the banks together by a large *balvardo* built round each of the towers at the angles of the ancient circuit of wall. In the plan which he has given of a place thus fortified,* these works have a great resemblance to the counterguards in Vauban's Second and Third Systems; and the idea may be considered as the first step to the formation of large bastions in such situations. In the covert-way surrounding the ditch, the same engineer proposes to place circular redoubts, with loop-holes in the walls, as stations for a guard; and such redoubts seem to have been the originals of the places of arms, subsequently formed at the re-entering and salient angles of that part of the fortifications. Having given the dimensions of the great ditch and glacis from the writings of Cataneo and Tartaglia, he points out the advantages which would arise from continuing the glacis at its foot below the level of the ground, to form what may be called an advanced ditch; observing that it would impede the progress of the enemy in making the assault, and would prevent his retreat if repulsed. Castriotto observes that there then existed in France many places surrounded by what he calls a *fossa brea*, (*fausse-braye*,) or outer circuit; and from the view which he has given, it appears to have been simply a wall detached from the foot of the main rampart.

Places of arms, and fausse-braye.

Rapid adoption of the Bastion System throughout Europe.

The inventions of the Italian engineers in the Art of Fortification must have been very early adopted in the North of Europe: for we find, that in the time of Charles V., Emanuel of Savoy, the General of that Emperor, built Hesdin near Amiens with spacious bastions, whose distances from each other seem to have been regulated by the range of muskets. And the citadel of Antwerp, which is thought to have been the first regular fortification constructed in that manner, was built in the reign of Philip II. of Spain. In the time of Errard, however, who wrote in A. D. 1594, we find that large bastions, or *boulevards*, as he sometimes designates them, had been generally introduced either as outworks in front of the round towers of ancient fortresses, or to supersede the latter entirely; and, in the designs which that engineer has given as then new, they always form part of the circuit, and are constructed at the angles of the polygon as in modern fortifications. But their flanks, which are double or triple, are short, and are protected by circular or rectangular orillons. Errard speaks† of ravelins and bastions as of detached works, added in front of the curtains between two small towers; and when the curtain is long, he proposes to have two such works, either separated from each other, or connected by a curtain, and he denominates the whole a *tenaille*, expressly stating it to be of use in affording room for the defenders, which was wanting in the ancient circuit. It is remarkable, however, that he has shown ravelins of the modern kind in only one of his own designs; and in that they appear to be without ditches, and to resemble merely re-entering places of arms. We may add to this brief account of the works of one who may be considered as the father of French military engineering, that he has given‡ an example of a front of fortification, in which counterguards are traced in such a manner as to cover the faces of a large bastion: he does not, however, recommend them, alleging the expense of their construction, and the probability that the enemy might place artillery upon them for the purpose of breaching the inner wall. On the other hand, he proposes, in order to prolong the defence, that good retrenchments should be made in the interior of a bastion, or at its gorge, by a rampart formed either in a straight line or in the manner of a tenaille. Ravelins or bastions, connected by curtains, so as to form one or more fronts of fortification, as they are now called, and therefore resembling modern horn or crown works, are also recommended by Errard,* to serve as defences for a bridge, or to cover the suburb of a town.

Its developement by Errard of Bar le Duc, the father of the modern Art of Fortification in France.

Remarkable example of its early adoption in England.

The Italian system, which, nearly as soon as it can be said to have been formed, was, as we have seen, introduced into Flanders and France, appears to have been about the same time received in England; and, among the small number of military constructions which our Country can boast, it happens that one belongs to the first Age of modern Fortification. The example we allude to is exhibited in the works about Carisbrooke Castle in the Isle of Wight. That interesting fortress may pass for one of the most ancient in the Country, (even though we should not assent to the opinion of Dr. Stukely, that it was originally built by the Emperor Carausius,) since mention is made of it in the Saxon Annals. It is supposed to have been enlarged soon after the Conquest; and the grand entrance, on the Western side, was built during the reign of Edward IV. The old wall of the Castle is of a pentagonal form; it has a lofty keep on the North-East side; and besides the small towers at the angles, which are disposed with a salient angle to the front, there is, on the middle of each of the walls connecting them, a rectangular projection having one side parallel to the length of the wall, probably for the purpose of defending the faces of the collateral towers. In the time of Elizabeth the Castle was surrounded by fortifications, enclosing an area considerably greater than that within the ancient walls, and having the parapet on a much lower level than the summit of those walls. These fortifications are constructed on an irregular pentagon, with bastions at the angles; and on two of the fronts the flanks are simple and rectilinear, but on the others they are protected by rectangular orillons. The rampart is revetted with a stone wall; and in each of the retired flanks, which are perpendicular to the curtain, are two apertures, intended as embrasures for small pieces of artillery. On two of the fronts of fortification there is, between the flanks, a bank of earth in the form of a modern tenaille; and beyond the ditch, in what may have been a sort of re-entering place of arms, there still remains a small elevation of earth, of a semicircular form, apparently intended as a ravelin, or, as this kind of work was sometimes called, a half-moon. In the area between these fortifications and the Norman walls, are elevations of earth which appear to have served as traverses, and as cavaliers to give the defenders, in the manner of the works of that Age, a command over the neighbouring heights. On one of the bastions is inscribed the year 1568, and the works are said† to have been executed by an Italian engineer named Genebella,

Carisbrooke Castle.

* *Della Fortificatione delle Citta*, lib. ii. c. 24.
† *La Fortification réduite en Art*, liv. iii. ch. v.
‡ *Ibid.* liv. ii. ch. x.

* *La Fortification réduite en Art*, liv. iii. ch. ix.
† Vide *Beauties of England and Wales*, vol. vi.

who was brought from Flanders for the purpose. Their great resemblance to the fronts of fortification in the System of Errard, who was contemporary with our illustrious Queen, may, with what has been before said, be considered as a proof, that in her days the new method of fortifying places was practised nearly all over Europe.

PART II.

MODERN SYSTEMS OF FORTIFICATION.

CHAPTER I.

General Description of a Modern Front of Fortification.

For the general appearance of modern fortresses, vide plate i. fig. 2.

Having briefly traced the History of the Art of Fortifying from the earliest Ages to the period at which the general adoption throughout Europe of the Bastion System may be said to have introduced and established all the most essential principles in the Modern Science of Defence; we may next proceed to give some account of the various forms of construction for fortresses which have been since practised or proposed. Before, however, we enter on this description, it will be proper, in order to render it more intelligible to the general reader, to explain the form of a rampart and parapet, and the nature of the works which constitute what is called a front of fortification. Fig. 1, plate ii. represents the plan of a front with its outworks; and fig. 4 is a profile or section taken on that part of the plan which is designated by the dotted line A B. A horizontal plane passing through this line in fig. 4, represents the plane of site or level of the country; and *a b c e i* is the mass of earth forming the rampart and parapet: the earth is procured by excavating the ground in front; and this excavation constitutes the main ditch, the profile of which is *v r s t*. The line *a b* is the interior slope of the rampart; and this is made gentle enough to permit the defenders to ascend or descend it on occasion with tolerable facility. The line *b n* is the *terreplein* of the rampart, or level space on which the troops and cannon are placed for the defence; and its breadth is from thirty-six to forty-two feet, to allow of a free circulation in rear of the guns when in battery. Its part *c n* is the banquette or step, on which the soldiers stand to fire over the parapet; and it has a slope *m c* towards the rear, the base of which is equal to twice its height. Again, *d e*, the height of the parapet, is so regulated as to procure sufficient cover for the men and guns upon the terreplein. When the fortifications are constructed upon a level plain, seven feet and a half suffice for this purpose. The superior slope *e f* of the parapet is directed as nearly as possible to the edge *t* of the opposite side of the ditch, in order that a man, when firing over the parapet, may without difficulty see the enemy there. The line *f i* is the exterior slope of the parapet, which being made of earth stands upon a base equal to its height, for the sake of stability. The thickness of a parapet at its upper surface is generally about eighteen feet, that the work may not be pierced by shot from the heaviest artillery. The *revetment*, or wall of masonry (*i r p*) supporting the rampart, is made of such solidity, that its resistance may be more than equal to the pressure of the earth above and behind it; and *o p* is the buttress or counterfort placed behind the revetment, to increase the strength of the latter. The buttresses are placed at distances from each other of fifteen or eighteen feet, reckoning from centre to centre, as is shown in fig. 5, which represents a portion of the ground plan of the masonry on both sides of the ditch. The height of the wall *i r* should be so great as to render escalade very difficult or impossible; and for this purpose thirty or thirty-five feet may suffice. Nevertheless, its top *i* is not allowed to rise above the level *l k* of the crest of the parapet of the covert-way: the reason for which is, that no part of the masonry should be discernible from the enemy's distant batteries, lest being breached from them, the parapet should fall, and thus expose the terreplein of the rampart.

Form of the different parts of works. Vide plate ii. figs. 1 and 4.

Rampart.

Parapet.

Revetment, or sustaining wall.

Buttresses, or counterforts. Fig. 5.

Ditch.

From what has been said, it must be evident to the reader, that the depth of the ditch is almost a fixed quantity: since it must depend upon the necessary height of the *escarp*, which is the name given to the outer face of the rampart. This is particularly the case when the ditch is a dry one: but there is no such absolute necessity when the latter contains a depth of water equal to six feet, which is deemed sufficient to prevent the enemy from wading through it to the assault, or to surprise the place. The breadth of the ditch must, in a great measure, depend upon the nature of the soil. If dry, the least breadth it ought properly to have should be equal to once and a half the height of the rampart: in order that the rubbish of the breach may not extend across it, and furnish the enemy's sappers wherewith to commence their passage, after they have pierced through the wall *t s*, which terminates the ditch on the side next to the Country. It may be added, that a dry ditch, if very narrow and deep, opposes an almost insurmountable obstacle to the enemy when he would destroy the escarp: since it renders him unable, from the crest of the glacis, to see the wall sufficiently near the foot to allow a practicable breach to be made; or obliges him to form his batteries on the terreplein of the covert-way, in which situation they must be roofed, in order to secure his gunners against the hand-grenades which the defenders may shower on him from the parapet. In these circumstances the besieger would probably resort to mines, as the only means of effecting his purpose: but here again he might be opposed by expedients of a similar nature, of which we shall give a description in its proper place. If, however, the ditch be a wet one, and that the enemy cannot possibly drain it, the wider it can be made the better; as the difficulty of forming a fascine passage across it will augment in proportion to its width.

Covert-way.

The opposite side of the ditch is called the *counterscarp*, to distinguish it from the escarp. This ought always to be supported by a masonry revetment *t s*, of

Fortification.

more complicated: in order to screen at least a small portion of the artillery of fortresses from the sweeping ricochet fire, which his own practice had introduced; and to prolong the defence after a breach should be formed in the face of a bastion.

His First System.

The method which he seems generally to have followed in his constructions up to the year 1688, and which writers have denominated his First System, differs in many points of detail from that of Pagan. He makes the distance between the salient angles of the nearest bastions equal to three hundred and sixty yards; See fig. 11. and, in assigning this length to the side of the exterior polygon, he was influenced by the consideration that the range of the wall pieces, by which the defenders of the flanks were to oppose the construction of the enemy's counter-battery on the crest of the opposite glacis, was equal to about three hundred yards. For, thence taking off forty yards for the supposed breadth of the main ditch and the covert-way, there would remain two hundred and sixty yards for what is called the length of the *line of defence;* and to this adding one hundred yards for the face adjoining to the flank, on which the defenders were stationed, the front of fortification will be found of the length above-mentioned. Vauban's reason for making the faces of the bastions equal to about one hundred yards in length, was that, in the inferior polygons, there would then be sufficient breadth at the gorge to allow a free communication between the bastion and the interior of the place. He then traced the flanks in directions forming angles of about eighty-one degrees with the lines of defence, in order that the fires from thence might take in reverse the assailants when in the act of storming the breach made in the face of a collateral bastion. The length of the flanks must evidently depend on the angle at which the lines of defence intersect each other; and this was determined by letting fall from the middle of the side of the polygon, towards the interior, a perpendicular to that side, and making its length equal to one-sixth of the length of that side in all polygons greater than the pentagon. The extent of the flank thus became somewhat greater than that of the battery which the enemy could construct to dismount its guns: while the flanked angle of the bastion continually increasing with the number of sides in the polygon, the interior of that work became proportionally more capacious, and its faces less liable to the action of the ricochet. The above rules of construction also render the curtain joining the flanks of two bastions long enough to permit the defenders of those flanks to see the whole of the ditch between them; and it is therefore evident that no attempt of the enemy to surprise the enceinte can succeed.

The earlier modern engineers had, with a view of increasing the defence of the enceinte, surrounded it with a *fausse braie*, or attached parapet on a lower level than the principal one: but this work being subject to several defects, particularly to a plunging fire from the enemy's lodgements on the glacis, was superseded by the *tenaille*, an invention of Vauban, who constructed it, for the first time, when ordered to repair the citadel of Lille, for the purpose of covering the postern in the curtain, and defending the main ditch and the terreplein of the ravelin. He also directed the counterscarp towards the angle of the shoulder of the opposite bastion instead of drawing it parallel to the faces, as in Pagan's outline; by which he gained the advantage of laying open the whole of the ditch to the fire of the flank, which otherwise was in some polygons intercepted by the re-entering angle of the counterscarp. He augmented considerably the size of the ravelin; making its faces about equal in length to those of the bastions, and directing them to points taken on the bastions at ten yards from the shoulder-angles, in order to cover, in some measure, those shoulders from the fire of the enemy's counter-batteries at the salients of the ravelin. He made the re-entering places of arms more spacious than they were before; gave ten yards to the breadth of the covert-way; and placed traverses across the latter, at certain intervals, to increase its means of defence, and protect the men there from the effect of the ricochet.

His Second System.

Notwithstanding all these improvements in the System of fortifying, many ameliorations were yet requisite to keep pace with the ascendant which the attack was rapidly gaining over the defence. The numberless instances of capitulations being made as soon as a breach was practicable in the body of the place, owing to the unwillingness of Governors to risk the consequences of an assault, convinced Vauban that some contrivance must be resorted to, which would obviate the evils of dependence on a precarious retrenchment made during the siege. With a view to this object, when instructed to fortify Landau, he separated the bastions from the body of the place by a ditch about forty feet wide, in order that, after the breaching and capture of the bastions, the besieger might be compelled to recommence operations against the enceinte. The angles of the latter were fortified by small pentagonal towers of masonry, called tower bastions: underneath See fig. 12. which he contrived casemates for two guns in each flank, and bomb-proof barracks for the troops along the faces, besides powder-magazines in the centre. This mode of fortifying is distinguished by the name of *Vauban's Second System:* but Béfort is the only fortress besides Landau, where it has been executed. The System, although in some respects stronger than the preceding one, left nevertheless much room for improvement, of which Vauban seems to have been aware: for in fortifying Neu Brisack, he increased the size of the ravelin, and gave it a redoubt. The tower bastions were likewise made larger; and the curtain which united them was broken inwards: so as to form two small flanks, underneath which casemates for cannon were constructed, to cooperate with those of the tower bastions in the defence of the ditch. This assemblage of works constitutes what is commonly, but perhaps improperly, called *Vauban's Third System:* for that great engineer did not himself write on the fortification of places; nor does it appear that he ever professed to follow any exclusive method in his constructions; but rather that he always adapted the nature and disposition of his works to the circumstances of the surrounding ground. Both these latter Stystems, although calculated to prolong the defence, were of much too expensive a nature to admit of being frequently put in practice in any state. An opinion moreover has very generally prevailed, that the smoke from the priming would render it impossible to remain in the casemates during the firing of the guns, owing to the want of ventilation. To ascertain whether or not this prejudice was well founded, the French Convention, in the year 1792, ordered an experiment to be tried in them by General the Citizen Desnoyers. This was done in the presence of the Governor and all the Garrison Staff of Neu Brisack. The result proved that the casemates

His Third System. See fig. 13.

Fortification.

under the flanks of the tower bastions were perfectly serviceable, however briskly the fire might be kept up in them; and that the small ones under the curtain flanks were equally so, provided the gunners were relieved every quarter of an hour. In both cases, however, it appeared that loose powder ought to be substituted for tubes as priming; and that, for firing, slow match should be used in lieu of port-fire, the smell and smoke from the former being less offensive.

COEHORN.

For the sake of chronological exactness, we shall next notice Coëhorn's Systems, although their exclusive appropriateness to marshy soils might fully justify our speaking of them separately, without interrupting the present sketch of the progress of improvement in the Art of Fortification. Coëhorn was the Vauban of the United Provinces; and like his great contemporary, he excelled in the Science of Fortifying, and of attacking and defending places. His talents and achievements accordingly raised him to the highest posts in the service of his Country; and the works which he has executed justly entitle him to the admiration of the Military World. His ideas were adopted, with such modifications as localities rendered necessary, at Nimeguen, Breda, Manheim, Namur, and Bergen-op-Zoom. In A. D. 1685 he published his three methods for constructing the fortifications of places: the First, which he formed on a hexagon, was intended to be raised on a soil, underneath the surface of which water is supposed to be found at a depth of four feet; his Second System is formed on a heptagon, and is adapted to a soil three feet above water; and his Third is on an octagon traced on ground five feet above water. The principal aim which he had in view was both to cover and flank his works more effectually than had until his time been done; to deprive the enemy of the space necessary for his batteries, and of soil for his approaches in the dry ditches; and moreover to surround him with cross fires whenever, by dint of perseverance, he might have penetrated into the works.

His First System.

From the brief view which we are to give of the means employed to arrive at these ends, it will be evident to the reader that the reason why Coëhorn exclusively chose marshy soils for the sites of his Systems, must have been that he had the interests of his native land alone in view; and that he would have succeeded equally well in appropriating defences to localities of any kind, is manifest from the merit displayed in the construction of Fort William at Namur. In his First System he has a capital or interior bastion, the revetment of which is hidden from the enemy's first batteries by the unrevetted face of an exterior bastion. This unrevetted or low face has between it and that of the capital bastion a dry ditch, the surface of which is but six inches above the natural level of the water, by which means it is rendered impossible for the enemy to establish himself in this ditch without undergoing the laborious process of bringing soil with him from the rear for the purpose of cover. This dry ditch is defended by six guns in a casemate under the stone tower placed at each shoulder of the exterior bastion; and the tower being unconnected with the flank of the capital bastion, covers it completely without taking up any portion of its length. A vaulted and loop-holed gallery extends along the interior of the low exterior face underneath the banquette, and communicates with the casemate in the tower; there are numerous doors made in this gallery to facilitate the egress and ingress of sorties; and it is moreover partitioned off at every eighteen feet by strong doors, that it may be defended foot by foot. Another considerable advantage which it possesses, is that of serving as a gallery of mines, from whence any lodgement which the enemy might attempt upon the low unrevetted face may be destroyed. Besides these defences, the dry ditch has a palisade provided with numerous barrier gates, extending along the front of the escarp of the capital bastion; and the space thus enclosed is swept by two guns placed at each extremity, or near the shoulders of that bastion. A vaulted, loop-holed, half-buried communication passes along the capital of the dry ditch, from a gallery of mines at the back of the escarp of the capital bastion, to the gallery under the exterior face. This communication, or covered caponnière, being partly sunk under ground, is necessarily made cistern-like, owing to its being beneath the natural level of the water, which, when the defenders are obliged to abandon it, may be let in by means of a sluice to prevent its being of any service to the enemy. The stone tower before mentioned is separated from the dry ditch by a small wet one, twelve yards wide, defended by three guns placed behind a wall at its interior extremity. The communication over this ditch is by two bridges: one conducts to the space without, and the other to that within the palisades above mentioned. Another small wet ditch situated in front of the orillon, or stone tower, and of the flank which connects the latter with the curtain of the enceinte, serves as a harbour: it communicates with the main ditch by a covered passage for boats, rafts, &c. The dry ditch between the flanks of the capital and exterior bastion, is defended by four pieces of cannon placed in a casemate, which is formed in the part of the curtain joining those flanks: through this there is a postern communicating with all the lower works.

See fig. 14.

The main ditch is defended by three flanks: that of the capital bastion; that of the inferior bastion; and that of the tenaille, or, as it may be called, the lower curtain. The latter flank is kept lower than the curtain and face with which it is connected, in order to allow the fires from the works in its rear to pass over it; and the curtain and face have a greater relief given to them, the first that it may the better cover the principal curtain, and the second that it may more effectually screen the low flank. A communication is made into the space between the two curtains, by means of a postern in the middle of the enceinte. The capital ravelin is revetted; and in front of it is a dry ditch, which is covered by the unrevetted rampart of the exterior ravelin. This dry ditch is defended by the faces of the capital and lower bastion, by the upper part of the tower, and by the double fire from the *coffers* or splinter proofs, which are formed across its extremities, near the main ditch. It moreover derives a defence from a covered caponnière joining the salient angles of the exterior and interior ravelins, similar to that already described, in the dry ditch of the bastion; and from a row of palisades extending along the foot of the escarp of the exterior ravelin. The two splinter proofs are screened from an attack by storm, by a small wet ditch, which is defended by a loop-holed gallery under the face of the lower ravelin. This loop-holed gallery serves as a communication into the dry ditch of the ravelin, for which purpose doors are made at its extremities; and a postern placed under the face of the capital ravelin completes the communication to the interior of the latter. The passage

Fortification.

Fortification.

from behind the splinter proof to the space enclosed between the palisades and the escarp, is by a small bridge. There is likewise a postern passing under the capital of the revetted or interior ravelin into the caponnière. The three flanks which defend the main ditch can only be counter-battered from the earthen counterguards which cover the bastions: but as these consist only of a parapet and a double banquette, the enemy would be unable, from want of room, to establish a battery on them. The covert-way is of a great breadth, (seventy-two feet,) and it slopes gradually inwards to the water's edge. The faces of the re-entering places of arms are provided with loop-holed coffers or splinter proofs, for the defence of the glacis by a double and grazing fire. A loop-holed wall serves as a redoubt to the place of arms; and palisades placed along the branches, faces, traverses, and in front of the above-mentioned redoubt, complete the defensive dispositions of the covert-way.

We shall not attempt any detail of the advantages and defects of the System just described; nor the mode of attacking or defending it: for the curious reader may find them in the Author's own Work. But it is allowed by the ablest engineers, that notwithstanding some little imperfections, (and the whole invention it must be remembered was prior to that of ricochet firing,) this System is capable of the most obstinate resistance, by the numberless expedients which it enables the besieged to oppose to the assailants. It may be added, that it would also require to be very judiciously and most vigorously attacked; and that the siege could only be abridged by the simultaneous employment of a very numerous artillery, and by the developement of new means. One of these would probably consist in firing shells into the earthen masses of the counterguards, with a view of producing explosions therein, similar to those of small mines; for cannon has been found to produce too slow and too imperfect an effect.

His Second System. See fig. 15.

Coëhorn's Second System, which he applies, as was said above, to a heptagon, consists of a capital revetted bastion, the upper and middle flanks of which are covered by the projection of the orillon. A wide dry ditch extends round this capital bastion, having its surface nearly on a level with the water. This ditch is covered by an unrevetted rampart, underneath which is a gallery, with loop-holes looking into it, in order to afford a reverse fire upon the enemy when he may have penetrated so far. The ravelin with retired flanks is connected with an unrevetted rampart surrounding the enceinte; and a low curtain, or in other words, a tenaille with flanks, in front of which is a small wet ditch, covers the curtain. By this disposition, the whole of the enceinte may be defended with still greater advantage than in the First System, by strong sorties of cavalry as well as infantry. A row of palisades extending along the dry ditch in front of the capital face, covers the retreat of the troops. An uninterrupted counterguard, placed beyond a broad wet ditch, forms a third enceinte or envelope; each branch of which is divided and flanked by a traverse; and a ditch and covert-way, similar to those of the First System, surround this third enceinte. The advantages of this System consist in a greater facility of communicating with the second enceinte, and of defending it by numerous bodies of troops of all arms, owing to the uninterrupted continuity of the broad dry ditch; and in the economy of its construction, it being much less expensive than the First System.

His Third System.

Coëhorn's Third System is that which he himself most esteemed; but as no one agrees with him on the subject, and as it has never received the honour of execution, and is moreover the most expensive of the three, we shall not, in the limited space allowed us, enter into a minute detail of its construction or uses. The reader is by this time sufficiently familiarized with the subject to be enabled, by an inspection of the figure, to form a competent idea of the defensive dispositions contained in it. See fig. 16.

CHAPTER III.

Improvements subsequent to the Age of Vauban and Coëhorn.

In returning to the fortifications which are applicable as well to dry as to wet soils, we shall pass over in silence the throng of Writers, contemporaries or immediate successors of Coëhorn and Vauban, such as Borgsdorf, Sturm, Herlire, Glasser, &c.; and proceed immediately to Cormontaingne, whose valuable improvements on the ideas of Vauban, give him a claim to the honourable distinction of being the principal disciple of that illustrious engineer. From the general merit of its defensive properties, joined to economy in materials, the Method of Cormontaingne may, perhaps, be considered as that which is most likely to be adopted as a basis of construction when circumstances shall require the formation of new, or the restoration of any existing fortresses.

Cormontaingne's Method. Fig. 17.

Cormontaingne places the points of his bastions at the same distance as that prescribed by Vauban in his First and Third Systems: that is, three hundred and sixty yards. The magistral line of his front of fortification is traced in nearly the same manner as in the Systems of Pagan and Vauban: that is, the positions of the lines of defence, or the produced faces of the bastions, are determined by the length of a perpendicular, let fall from the middle of the side of the exterior polygon. The faces are made one hundred and twenty yards long; and the flanks are at right angles with the faces of the opposite bastions, in order that the fires from thence may effectually graze those faces. In making the face of his bastion longer than Vauban did in his original method, he certainly shortens the flank, but he brings the latter closer to the object which it has to defend. The augmentation of size in the bastion, renders it capable of containing such interior retrenchments, as may enable the body of the place to sustain many assaults ere it be forced to capitulate. Of the nature of these works in reserve, mention will be made under the head of Interior Retrenchments. The crest of the counterscarp of the main ditch is drawn towards what is called the interior shoulder angle of the collateral bastion: that is, towards the point on the plan which represents the meeting of the crest of the parapet on the face and flank; by which means the direct fire of a man stationed at the shoulder will graze the exterior side of the ditch. In order to correct the principal defect of Vauban's ravelin, which does not sufficiently cover the central part of the enceinte, Cormontaingne has constructed his upon a larger base. Having also made it without flanks, he has reserved the latter for the redoubt in its interior, from which the besieged will be enabled to have a

reverse fire upon the breaches of the collateral bastions; so that the assault on the latter becomes impracticable, until after the entire capture of both the ravelin and its redoubts. It is only by giving greater saliency or projection to some of the works, that a simultaneous attack upon the whole of the defences may be prevented; as otherwise the enemy being able to embrace the whole at once, would not be compelled to attack in detail what might be carried by a single operation. Cormontaingne, therefore, makes his ravelins project considerably beyond a line joining the salients of the collateral bastions; and thus the enemy becomes unable to attack the latter until he has gained possession of the former, on account of the reverse fires which might from thence be directed upon his reproaches. The taking of the bastions is therefore retarded by the time which must be spent in working up their glacis after the ravelins have fallen.

These were not the sole improvements now effected in the ravelin. Cormontaingne observed, that in those works at Neu Brisack, Vauban had given such a breadth to them, that not only could the enemy there find room to establish batteries for breaching the redoubt, but the latter was by this same reason diminished to an almost insignificant size. He therefore reduced the ravelin to the smallest breadth possible, consistently with the necessity of placing guns on it for the defence; and he augmented the size of the redoubt so as to render it even capable of being retrenched, and of covering from the fire of the enemy's lodgement at the salient angle of the ravelin, the *coupures*, or traverses, which might be placed near the lower extremities of the faces of that work in order to prolong its defence.

Cormontaingne also proposed to trace the demigorges of the ravelin and its redoubt, in the directions of lines drawn from the flanked angles of the collateral bastions, through the interior extremities of the parapets of the former works: by this construction there is free space afforded for the fire of artillery in casemates formed in the flanks of the redoubt, into the breach made in the face of a collateral bastion; and the passage from the caponnière into the main ditch is concealed from the view of the enemy when he has crowned the opposite crest of the glacis. To afford to the covert-way, and particularly to the long branches of it in front of the ravelin, a powerful support, which might enable it to oppose an obstinate resistance, and allow of sallies being made to destroy the enemy's lodgements even after they were effected, he constructed redoubts or retrenchments in the re-entering places of arms, with revetted escarps and counterscarps, and for this purpose he considerably increased the size of those places of arms.

In any System of Fortification with small ravelins, the besieger has it in his power to breach, at the same time, two bastions and the intermediate ravelin: whereas in the Method of Cormontaingne, it becomes indispensable, when it is desired to attack two bastions, to take three ravelins; and the attack of one sole bastion entails that of the ravelins on each side of it; unless the place be surrounded by a polygon of a very few sides. Whenever the besiegers are able to breach and assail two bastions at once, it is evident that the attention of the garrison must be divided and consequently weakened; and in this respect the System of Cormontaingne has a decided advantage over that of Vauban: for when the attack can embrace no more than a single bastion and two ravelins, the enceinte being breached in one place only, the defenders have it in their power to concentrate all their forces at that place, in order to oppose the last assault. But from the octagon upwards, the necessity of attacking several ravelins can with great difficulty be eluded by the besieger; and this necessity increases in polygons of a greater number of sides, in proportion to the magnitude of their angles. Hence it follows, that when two or more contiguous fronts are developed upon the same straight line, this property arrives at its maximum; and that it becomes impossible to conduct the attack between two ravelins against the covert-way of a bastion by the ordinary process. The property also which the ravelins possess of seeing, reciprocally, in reverse the enemy's lodgement on each other's covert-way, increases also in intensity with the size of the polygon, and likewise attains its maximum on the straight line. The covert-way, with the exception of the places of arms and redoubts already mentioned, remains nearly the same as in Vauban's constructions.

The figure of which we have made use on Plate ii. to explain the names and uses of the different parts which constitute what is called a front of fortification, is constructed upon the Modern System, or in other words, Cormontaingne's Method, with such improvements as modern engineers have thought it expedient to add. The ravelin is made to cover the shoulders of the bastions more effectually, and as great a projection is given to it as possible, consistently with the necessity of keeping its salient angle within the limit of sixty degrees. Each of its faces is retrenched by the *coupures* or cuts through the rampart at *p p*, which prevent the enemy from taking the redoubt of the re-entering place of arms in the covert-way in reverse, without first possessing himself of the redoubt in the ravelin: when the above retrenchments of course fall of themselves. The direction given to the faces of the redoubts *o o* in the re-entering places of arms more effectually prevents the enemy from enfilading them. that is, sweeping the whole of their length from batteries erected on the crest of the covert-way. The place of arms itself is here made circular, with the same view of avoiding the enfilade fire.

Modern System. Plate ii. Fig. 1.

The chief of all these improvements is the increased projection and size of the ravelins; but the credit of this cannot be justly claimed by modern engineers: it being well known that it was designed by Cormontaingne for his work of Belcroix at Metz; and that he was only restrained by the French ministry of that day from putting it into execution. Cormontaingne, likewise, had it in contemplation to make a difference in the depth of the main ditch and that of the ravelin; from whence would have resulted three important advantages:

Its advantages.

1. The ditch of the ravelin being several feet less deep than the main ditch, the sudden declivity, which is supported by a wall, would prevent the enemy from turning the ravelin when he shall have got into its ditch; and would, moreover, compel him to blow down the wall, in order to make a descent into that of the enceinte.

2. Under cover of the sudden declivity, the troops of the garrison can circulate through the main ditch in perfect security until the enemy is established on the covert-way of the bastion.

3. The fire of artillery from the bastion's face along the ditch of the ravelin is rendered somewhat more grazing, and consequently capable of producing a greater effect against the enemy when he gains an entrance into that ditch.

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Fig. 4.

The revetments are likewise proposed by modern engineers to be made vertical, as shown in the profile, fig. 4, experience having proved that perpendicular escarps have some advantages over those to which a slope is given: as on the latter (even on many of Vauban's construction, which have a slope equal only to one-fifth their height) weeds are found to grow, which assist materially in their dilapidation. Many of the escarps above alluded to, in the French fortresses which were built in the reign of Louis XIV., are already, from this cause, falling into ruin: whereas many vertical walls standing near them, and which are of an earlier date, are still in good condition, exhibiting no signs of vegetation on them. It must not from this be concluded that Vauban was unacquainted with the fittest profile for a revetment. In fact, walls whose exterior faces are formed with a small slope, better resist the shock of breaching artillery, than those whose faces are vertical; and it may be added that the construction of the former is more economical than that of the latter, since, with a profile smaller in area, they present an equal resistance to the pressure erected against them by the earth composing the rampart and parapet. It is probable, therefore, that what are called vertical revetments can, with propriety, be only applied at the counterscarps of ditches which are, from their situation, but little exposed to the artillery of the enemy. Revetment walls are now occasionally strengthened by vertical or horizontal counter-arches. The former of these are portions of cylinders standing on their bases and connecting the tails of the counterforts; and their convexities are turned towards the mass of the rampart, that they may be better able to resist its pressure outwards: the latter are disposed in tiers, one above another, and rise from the sides of the counterforts: the arches and counterforts are but slightly connected with the front wall, that when the latter is destroyed by breaching, it may not bring down the others in its fall.

General objections to the Bastion System.

What has been hitherto said of the Systems of different engineers, relates exclusively to those in which the bastion outline has been adopted: but, although that method, with trifling variations, has alone been reduced to practice, it is here proper to notice some objections which have been raised against it. Foremost among the opponents of the Bastion System stands the French General Montalembert. He was, however, not the first: for Werthmuller, A. D. 1685, and after him Landsbergen, Augustus II. Elector of Saxony and King of Poland, Bollersheim, and Herbort, had written upon the superior advantages of a line of rampart which should present a succession of salient and re-entering angles. Into the value of the reasonings which have been offered in favour of such a disposition of the rampart, both on the ground of economy of construction and powers of defence, it is not here our province to enter. But though it may be easily proved that the Bastion System is not without many defects, yet, when the infrequency of opportunities for the erection of entirely new fortresses is considered, it need not excite our wonder, while we avoid to prejudge the question of comparative merit, that the proposed outline has never, in any instance, been practically tried to supersede those methods of fortifying which have so long been in use.

Suggestions of Montalembert for its alteration.

It must, however, be confessed by men of all opinions, that no Author on the Art of Fortification has exhibited greater ingenuity, than did General Montalembert in his numerous and varied combinations of the casemated System of alternate salient and re-entering angles; or in other words, the casemated tenaille System, which he published A. D. 1776. Several enceintes situated within the main ditch; a formidable artillery placed in bomb-proof casemates; and these serving likewise as a cover for the garrison, for stores of every kind, and even for the inhabitants: such is the system which the author proposes to substitute for that of Vauban, the defects of which, he observes, are acknowledged by the best engineers. Vauban clearly showed that his Art of Attack was much superior to his Art of Defence; and he left to posterity the task of remedying the imperfections of the method which he had followed: in attempting which it is evident that two conditions must be adhered to; first, that the new method shall not be more expensive; and secondly, that it shall not require a stronger garrison than the old one. To increase the means of defence under these limitations, is the problem which Montalembert proposes to solve. We shall not undertake to analyze the systems contained in the whole of his eleven quarto volumes, composed, it is said, after he was sixty years of age: but shall confine ourselves to a cursory view of one or two of his principal contrivances, referring the curious reader for the rest to the Work itself.

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See fig. 18.

After pointing out the defects of the Bastion System, as executed in most fortresses, Montalembert proposes suppressing the tenaille and curtain, and producing the faces of the bastions inwards to their junction with the flanks of the redoubt in the ravelin, likewise produced inwardly. A hundred toises of rampart would by this means be saved; the flanks would be better covered than they are at present; and their fire would be more certain, because the line of defence would be so much shorter. But if it be desired to preserve the same length of line of defence, by producing the faces outwards an exterior side of three hundred and six toises would be obtained for the side of a heptagon, inscribed in the same circle as a dodecagon whose sides are one hundred and eighty toises long in the Systems of Vauban: whence would result for a defence equal, as he asserts, to the latter in other respects, a saving of one thousand three hundred and thirty-six toises* of rampart in the body of the place. By adding to this the suppression of five ravelins and as many redoubts, there would be economized eighteen thousand nine hundred and twenty cubic toises of masonry. It is true that such a fortress would have but one enceinte like most others in actual existence, which being once perforated would leave the garrison without resource; and for this reason the author proposes, in a second System, said to be *à ailerons*, to form a triple enceinte within the main ditch by producing the curtain to the capitals of the bastions. This enceinte he defends by a casemate placed behind the redoubt of the ravelin; to the faces of which redoubt he adds flanks defending the ditch. The retrenchments of the bastions constitute the second enceinte, which is defended by the wings annexed to the redoubt; and he places a casemated traverse across each face of his ravelin. All the communications between the different works are well covered; and all objection to dead angles is done away with by an appropriate arrangement of casemates. The small space on the rampart of the ravelin, and on that which is substituted for the bastions' faces, will scarcely allow of artillery being placed on

* The toise is equal to 6.3945 English feet.

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them by the besieger, with a view of opening the works within: he would besides, in such a situation, be battered in front and in flank within pistol range. Works arranged in this manner, although less expensive and easier to defend properly, are nevertheless greatly exposed to ricochet and shells; and Montalembert, desirous of procuring cover in old existing fortresses from the destructive effects of the latter, proposes making in them the following alterations.

Fig. 19 and 20. He would separate from their rampart the revetment walls of the escarp both of the bastions and ravelins, which may be supposed, as represented in fig. 19, to be those of a front of fortification constructed according to Vauban; and proposes to make the exterior slope of the ramparts of earth. He would lower the escarp walls, (as shown fig. 20,) lengthen the buttresses or counterforts, and make use of them as piers to the vaults which are to cover the batteries; by this he would obtain casemates open in rear and uninconvenienced by smoke. The tenaille is to be suppressed; and the curtain, as well as the retrenchments of the bastions, is likewise to be casemated for both cannon and musketry. A wall of masonry, traverses, and loop-holed guard-rooms, add to the interior defence of the bastions and ravelins. Another species of retrenchment which he proposes, is a casemated tower in the gorge of the bastion, by which the defence may even be continued after the capture of the place. Either one or the other of the above dispositions would, he conceives, oppose almost insurmountable obstacles to the construction of breaching and counter-batteries against them under such a powerful and covered fire of cannon and musketry.

After giving his attention to the means of improving already existing fortresses constructed upon the old plan, Montalembert allows full scope to his genius. He adopts what he calls the TENAILLE SYSTEM; and considering the defence of places to depend upon the greatest number of covered fires that can be opposed to the attack, he places casemates in all the re-entering angles of his

See fig. 21. wet, and also at the angles of his dry ditches. The faces of the tenailles are formed of a double casemated wall, behind which extends an earthen counterguard, whose interior slope falls into a wet ditch. A dry ditch encircles this counterguard and wet ditch, and passes along the foot of the capital rampart, the gorge of which is retrenched by a loop-holed wall, and by a casemated tower with an angular base. A general counterguard, or earthen rampart, surrounds the main ditch; and in its re-entering angles there are casemates, covered by lunettes with casemated flanks placed upon the counterscarp of the outer ditch. The communication from the body of the place to the outworks through the wet ditches is by a cistern-like caponnière, the cover of which serves moreover as a bridge. This double communication may easily be rendered useless to the enemy by cutting away or demolishing a portion of the bridge, and inundating the caponnière by means of sluice-gates at its junction with the place.

The advantages which the Author claims for this system are as follows:

1. The enemy will have to penetrate through four enceintes, of which the three principal ones are within the grand ditch, and under the fire of a numerous artillery unseen, and, consequently, indestructible by the enemy's batteries in the covert-way.

2. The covered fire of artillery which it opposes to the construction of breaching or counter-batteries, is superior to that which the enemy can bring, both in number and in the advantages of cover: so that the execution of those batteries will be a matter of extreme difficulty, if not altogether impossible.

3. Its communications with the outworks are safe; and thus the operations of the troops are greatly facilitated.

4. The tower and loop-holed wall at the gorges of the tenailles, serve as a last retrenchment, when even the enceinte has been carried.

5. The troops and stores are amply and safely covered; and have nothing to apprehend from conflagrations, which too often prove destructive to the defence.

Carnot's System. See fig. 22. The celebrated Carnot was a zealous admirer of Montalembert's talents, and publicly espoused his cause against the enemies of all innovations or improvements in the Art of Fortifying. The construction which he proposes is a System of casemated tenailles covering the body of the place, as in fig. 22. He places at the salient angle of the interior rampart a casemate containing one gun, to batter the saps which may be directed along the capital, and also two pieces of cannon upon each face and flank. The object of these last is to take in reverse any batteries opened against the faces of the collateral salients: two splinter proof batteries accompany the above casemate with the same object. The second enceinte consists of a counterguard merely broad enough for a parapet and banquette, so that the enemy cannot place cannon upon it. Its relief is so regulated that it may cover the casemate at the salient without masking its reverse fires; the covert-way is reduced to the breadth of two banquettes; and a single traverse protects its branches. The ditch of the body of the place is defended by a casemate; the under story of which, A, (see fig. 23,) Fig. 23. receives air by means of a ditch, B: this casemate extends beyond the alignement of the ditch, (see the plan, fig. 22,) in order to see the breach in reverse, and be itself unseen. The upper story alone is continued (on a level with the country) as far as the alignement of the covert-way, in order to defend the ditch of the counterguard: which ditch is terminated by a gradual slope towards the re-entering angle; and here the counterguard is but a mere parapet sufficiently elevated to cover the revetment of the body of the place. An opening is made in this parapet for the egress of sorties, which may also be made through posterns contrived under the shoulders of the counterguards. By this arrangement the besieged have the advantage of being able to make sorties both of infantry and cavalry with great facility, who issue from the ditches by the slope or ramp, which terminates, as already mentioned, at the re-entering angle; and even in the event of a repulse they would derive great protection from the salients. Cavaliers are placed at the gorges of the tenailles, if necessary; and these gorges are closed by defensive barracks and by loop-holed walls, calculated to stand an assault advantageously, or at least to compel the enemy to grant honourable terms of capitulation.

Carnot subsequently recommended a system of works which very nearly resembles that proposed by Cormontaingne. Its principal bastions, whose salient angles are distant from each other four hundred and eighty yards, are, however, detached from the body of the place, and cover a range of casemated batteries at the gorge of each. The bastions are themselves covered by narrow counterguards; and a vast ravelin, having in its interior a lofty redoubt or cavalier, covers the intermediate space. These works are

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of earth: but one detached loop-holed wall surrounds the body of the place; and another is placed before the faces and flanks of each detached bastion. This distinguished Mathematician and Engineer here dispenses with the covert-way; and he has made the exterior sides of the ditch to surround the fortress in the form of a glacis, sloping downwards from the level of the natural ground.

The principal means of defence proposed by Carnot consist in a series of engagements with the enemy by powerful sorties; and an abundance of vertical fires, of stones or small balls, made from thirteen-inch mortars placed at the salient angles of the works, and in the casemates in rear of the bastions: by all which the enemy, who is supposed to be collected in great numbers between the third parallel and the place, will be compelled to cover his lodgements with blindages, or roofs made of fascines and earth. A fire of musketry made at an angle of forty-five degrees with the horizon upwards is also recommended for the purpose of annoying the assailants behind their trenches. Among the proposed advantages of this system may be ranked the obstacle which the enemy must experience in passing the loop-holed wall before mentioned, which from its height will be not only difficult to escalade, but more difficult to descend on the interior side; while, being covered by the exterior works, it was supposed to be secure against any attempt of the enemy to breach it. To this may be added, the benefit arising from the countersloping glacis: which is not only convenient from the facility it would afford to the defenders in making sorties; but because it would expose the trenches formed in it by the besiegers to a plunging fire from the ravelin and counterguards. It ought to be observed, however, that the former of these advantages are compensated, by a corresponding facility afforded to the enemy when descending into the ditch to surprise the works; and since the principal ramparts are without revetments of masonry, it is evident that, after the detached wall is breached, which some experiments purposely made at Woolwich have proved possible, the enemy's troops, entering by the breach, may extend themselves along the front of the interior work, and mount in line over its parapet.

PART III.

ON THE MEANS OF INCREASING THE STRENGTH OF FORTRESSES.

CHAPTER I.

Nature of these Means.

Application of expedients for increasing the strength of fortresses.

WHAT has been hitherto said relates only to the construction of different works immediately enveloping the spots fortified; or in other words, to that of the body of the place, with its simple appurtenances of tenailles and ravelins. We shall now show the different expedients by which the strength of this envelope may be increased. But it should first be observed, that many places owe to the nature of their situation such advantages, as it would be difficult to procure by any contrivance of Art. We have a strong exemplification of this in the rock of Gibraltar; and in a part of the country surrounding the fortifications of Luxembourg: at the latter place, a bare rock extending over the accessible ground would, on account of the total impracticability of sapping in such a surface, oblige the besiegers to bring with them from a great distance their means of cover.

Enumeration of artificial means for this purpose.

Art possesses, nevertheless, many resources independent of those derived from Nature, and contributing to the same end. It may augment the duration of the resistance of a fortress by some one or more among the following means:

1st. Interior retrenchments: behind which the garrison, when beaten from the principal works, may renew the defence.

2dly. Counterguards: which must not only be taken, but even destroyed, before the works which they cover can be touched.

3dly. Great exterior works: which, as they cover one or more fronts, force the enemy to a preliminary siege before he can arrive at those points.

4thly. An advanced covert-way: which must be carried before the interior one can be attacked.

5thly. Detached pieces: or works placed so as to command the access to the place, and annoy the enemy with reverse fires.

6thly. Inundations: which drown the enemy's works at the commencement of the siege, and ultimately carry away his fascine passage across the ditch at the moment of his meditated assault.

7thly. Defensive mines, or countermines: which force the enemy to have recourse to the slower and more minute proceedings of subterraneous warfare to make sure his footing upon the surface.

8thly, and lastly. Casemates may likewise be included in this enumeration: notwithstanding the objections which many authors have urged against them.

Of their appropriateness to fortresses of different size.

All these may either be employed separately, or combined in different manners. We may nevertheless observe, that with the exception of inundations and mines, which can be applied to all kinds of places, according as the soil is best adapted to one or to the other, the use of the rest must depend upon the magnitude of the fortress. For instance, interior retrenchments, as they diminish the total space within the works, are but ill suited to small fortresses. Great exterior works, on the contrary, become such places peculiarly, owing to the increased area which they afford for military establishments. The case is far different with counterguards and advanced covert-ways; which, requiring an augmentation of defensive means, without furnishing additional room to contain them, would only tend to multiply the confusion and insufficiency of the interior resources; and such works are therefore only proper for large fortresses. On the other hand, a fortress, which from its size might be accounted of too great an extent, should in preference be reinforced by interior retrenchments.

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CHAPTER II.

Interior Retrenchments and Counterguards.

Interior retrenchments.

Interior retrenchments are works either constructed at the same time as the fortress itself, and constituting a part of its system; or else thrown up hastily during the siege to prolong the resistance, by cutting off the part of the rampart breached, and permitting the defence to be commenced anew behind a fresh obstacle. The insufficiency of such works when hastily constructed of loose soil; and the superior advantages which might be expected to result from their being carefully made beforehand, and revetted with masonry both at the escarp and counterscarp; were the reasons which induced Vauban to deviate from his usual mode of construction when ordered to fortify Landau. He accordingly separated the bastions from the enceinte, thereby converting the latter into one great interior retrenchment. Where such means of safe retreat exist, the garrison may with security stand the assault of the body of the place: they are therefore a most essential means of adding to the defence, and by them alone can the besieger be compelled to epaule himself across the ditch, and to make his lodgement upon the summit of the breach; which of all the operations of the siege are the most difficult and dangerous. The case is still worse if the retrenchment be of such solidity as to compel the enemy to use cannon, or the mine, in order to breach it. The difficulty of transporting heavy guns across the ditch and up the breach under the fire of the opposite flank, would naturally induce the besieger to prefer resorting to the latter expedient. But this being of much slower execution, the troops in his works on the crest of the covert-way, or occupied in the passage of the ditch, or in the lodgement on the breach, must all the while be exposed to great loss, under so close a fire of the garrison.

Sometimes composed of a small front of fortification.

These were undoubtedly the considerations which induced Cormontaingne to make in the bastions most exposed to attack, good permanent retrenchments with revetted escarps and counterscarps: and according to the shape of the bastions he regulated that of the retrenchments. When the obtuseness of the bastion left a considerable space between its shoulders, the form which he gave to the retrenchment was that of a small front of fortification: extending between two points taken on the faces at twenty or thirty yards from either shoulder, in order to preserve the whole length of the flanks for the purpose of defending by their fire the ditches and covert-ways of the collateral bastions. A retrenchment of this sort, with a ditch twelve yards wide, and surrounded by a covert-way, having a re-entering place of arms in its centre, would certainly be of great advantage in the defence: particularly if care were taken to give it a command of two or three feet over the faces of the bastions. It would enable the breach in the bastion to be defended with the greatest obstinacy, by the assurance with which it must inspire the troops of a safe retreat, if ultimately overcome. Besides, as the space included by the faces of the bastion diminishes in width the nearer it is to the flanked angle, it follows that, the retrenchment occupying the greatest space, the besieger is always out-flanked and combated by a superior force, during his approaches from the top of the breach towards the counterscarp of the retrenchment: the very reverse of the superiority which the besieger has enjoyed during the whole of the previous operations of the siege. The nature of this retrenchment also entails upon the assailant the necessity of repeating the operations of crowning the covert-way, passing the ditch, and breaching the work, since we have supposed that both escarp and counterscarp are revetted. Such are the difficulties which he must overcome if he should attempt to breach by cannon. If he choose the mine, he may meet with still greater obstructions from the defensive mines which the besieged may have prepared under the point of his bastion. So that, upon the whole, it does not appear that any exterior defence can be preferred to this species of retrenchment, which upon a fair valuation may be considered capable of adding twelve days to the defence; exclusively of the benefit which might accrue from the existence of mines underneath the bastion.

Retrenched cavaliers.

When, by the acuteness of the flanked angle, the interior space did not suffice for constructing the retrenchment in the form of a small front of fortification, with proper dimensions and relief, Cormontaingne gave it the shape of a cavalier. The faces and ditch of the cavalier were defended by *coupures en retirade*, or chequered retrenchments; the foremost of which cut the face of the bastion near the shoulder, and the other was sufficiently thrown back to prevent any part of the cavalier from being dead or deprived of fire. The cavalier had a command of eight feet over the bastion: but the coupures were on a level with the latter. This sort of retrenchment, although much better calculated to second the efforts of the bastion during the early part of the attack, is much less so when it becomes necessary to defend the space between it and the bastion. It therefore merits much consideration as a cavalier, and but little as a retrenchment. As the want of space between the cavalier and the bastion makes it impossible to have a covert-way, the defenders of the breach will not have sufficient room, and their retreat is not made good. The defence will therefore be neither obstinate nor animated. Besides, the narrow space between the counterscarp and the breach may be laid open by the enemy's mines: which will project the rubbish into the ditch of the cavalier, enabling the latter to be breached by the same batteries that breached the bastion, and thereby spare the besieger both trouble and time. It may therefore be repeated that, although this sort of retrenchment has the property of increasing the besieger's loss during the early part of the attack, the first has the more essential one of augmenting the duration of the siege, and making its end more disastrous to the assailant. The cavalier affords, nevertheless, the means of constructing under the mass of its terreplein good bomb-proof establishments; and this may in some cases cause a well-founded preference to be given to it over the other sort of retrenchment, which moreover cannot well be applied to bastions of a small size, owing to the narrow space between the shoulders. Two journals are given by Bousmard of the attack of a cavalier: the first case supposed being that in which there is sufficient space in front of the work for placing breaching batteries; and the second that wherein, from want of room for such batteries, the enemy would be compelled to have recourse to mining, in order to effect a gap for the purpose of breaching through it with the same battery which opened the bastion itself. In the former instance the work is deemed capable of a resistance of only six days, and in the latter of eight: being two days in favour of the smallest space between the cavalier and bastion.

A retrenchment *en tenaille* is made by uniting the

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Retrenchments en tenaille.

two shoulders of the bastion,—or rather two points taken on the faces at a few yards from the shoulders,—by two lines forming an obtuse re-entering angle. The ditch of the retrenchment is made ten yards wide, and the escarp and counterscarp, which are of masonry, have a height of eighteen feet. The parapet is on a level with that of the bastion. The communication made in the re-entering part is covered by a traverse, and provided with strong barriers, which is considered a better contrivance than a postern and stairs. But a tambour, or species of redan made with strong beams, may be constructed during the siege, as a tête, or immediate cover to the little bridge of communication. This retrenchment, infinitely more simple and less expensive than those already described, answers the object just as well, for it suffices to arrest the enemy's progress, and induce him to grant a capitulation; at the same time that it affords the besieged more space for an active resistance: that is, by sallying in greater numbers and attacking him in his lodgements, instead of remaining passively behind the parapets.

Rectilinear retrenchments at the gorge.

Another retrenchment still remains to be noticed; and that is the rectilinear retrenchment across the gorge of the bastion. Dufour (a modern author and engineer) thinks highly of it, and appears inclined to give it a decided preference. In the first place, it is economical; and being more distant from the breaches, it defends them better, and is itself less exposed to a sudden attack. Secondly, it leaves the interior of the bastion unincumbered. Thirdly, it may possibly be made to receive a defence from the two collateral bastions; if the besieged take care to demolish a portion of the parapets of the flanks at the moment the assault is to be given. This last advantage will suffice to retard the taking of the place two days: for when the defenders of the breach are compelled to retreat, the enemy's lodgement on its crest will receive a triple battery, two from the collateral flanks and one from the retrenchment itself. This, it is just to suppose, will force him to adopt measures of circumspection of a more than ordinary nature, to avoid being taken in flank when sapping up to the retrenchment. The besieged may therefore securely wait the moment of the enemy's establishing his cannon, to demand a capitulation. An oblique passage may be made at each end, directed upon the angle of the shoulder, thereby avoiding the enfilade from the lodgement on the breach. Each of these passages is covered by a *palanque*, or tambour, to ensure the retreat. The retrenchment at the gorge has the evil of diminishing by one-half the length of the flank: but this is obviated by leaving, entire and full, all that part of the proposed ditch nearest the flank, with the intention, nevertheless, of removing the mass in a moment of need, and of applying it to the formation of those portions of parapet, which, for the above reasons, have also been left incomplete. This will entail but a very trifling increase of labour, as it need only be done in the bastion or bastions attacked; and the trouble will be still less considerable, if the engineer, in constructing the place, has taken care to produce, as far as the flank, the masonry of the escarp and counterscarp of the retrenchment. The only part therefore which will be in permanent existence, is that comprised between the two passages. The two extremities may, until needed, be kept level with the terreplein of the bastion. The defence of a retrenchment thus situated will be more powerful, if the work be constructed in the form of a front of fortification; and, that the flanks of the retrenched bastion may be left entire, it will be only necessary to place the work in rear of the gorge, terminating its two faces in points taken on the curtain at twenty or thirty yards from the angles of the flanks. By this construction also the retrenchment remains unturned, if a breach should be made in the curtain by firing between the tenaille and the flank of the bastion.

Counterguards.

Counterguards are works solely destined to cover others of a more important nature: in such a manner that, without obstructing their fire, they shall preserve them from being breached until the counterguards themselves have fallen. The besieger will likewise be compelled to erect batteries on them, or else partially to destroy them by mines, in order to breach the principal works through the gaps produced from the explosions. The counterguard must, therefore, in the first place, completely cover the principal work, or at least all that part which may be exposed to breaching. It must be lower than the work which it covers, but must, nevertheless, screen its revetment. And, lastly, it must be made sufficiently narrow to prevent the enemy from finding room on it to place his batteries. As for the first condition, that of covering completely the principal works, it must be observed that the counterguards of the bastions, being terminated at the counterscarps of the collateral ravelins, always expose the bastions in rear to be breached through the *trouée* or opening of the ditches of those ravelins: unless, with a view of obviating this evil, counterguards be likewise applied to the ravelins; but then these terminating also at the counterscarps of the counterguards of the bastions, leave an opening through which the ravelins may be breached. It may therefore be considered a radical defect, inherent in such works, that access is always given to the enemy's breaching batteries against one or another of the principal works which they are destined to cover. It is true that the spots where such breaches are practicable, would be but difficultly reached by the enemy, and therefore the evil may perhaps be disregarded: except when it affects the body of the place, in which any kind of breach being productive of serious apprehension, is always dangerous, and seldom fails to serve as a pretence for capitulating. Besides the condition of covering the revetment of the principal works, without nevertheless obstructing their action upon the approaches, the counterguard must have all its interior commanded by the fire of that work. Whence it is evident, that the greater or less degree of command of a work over its counterguard must depend upon the breadth of the ditch which separates them. A work only fourteen yards broad between its escarp and counterscarp will not allow an enemy to construct any battery upon it, if its face be seen from any other which projects beyond it: because he must cut away the parapet of that which he occupies to obtain materials for the epaulement of his battery, and to make room for his guns: and this will evidently expose him to a reverse fire from such collateral work.

CHAPTER III.

Exterior, Advanced, and Detached Works.

Great exterior works.

Great exterior works owe their origin to the desire of occupying some important space in the immediate vicinity of a fortress: as for instance, a neighbouring height; the opposite banks of a river; or, in short, any

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portion of ground, the possession of which might procure some advantage, or remedy some defect. Such defences have since been constructed, however, under circumstances which seem to indicate a mistaken notion that, by multiplying the number of works about a place without judgment or discrimination, its strength is proportionally increased. Marolais complained bitterly of the abuse made of these means, and not without reason: since no less than three hornworks were crowded upon one sole front of the small fortress of Juliers, (A. D. 1611,) when the place was threatened with a siege. Besides the immoderate use made of hornworks and crownworks at the period of their invention, the manner of placing them was highly defective. For, their branches being directed upon the body of the place, and their ditches opening into the main ditch, it followed that the enemy, when once established upon the crest of the covert-way of the horn or crown work, could see and breach the wall of the enceinte through the opening of the ditches of the branches. To obviate this defect, Vauban proposed placing them with their branches and ditches directed upon the ravelins, which, however, only palliated the evil by transferring it from the enceinte to the outworks. Great exterior works, nevertheless, were so placed by his directions, for the first time, at Dunkirk, at Fort Nieulai, at Béfort, and at Huningen. The best position that can be given to these works, when their construction cannot be avoided, is beyond the main glacis; having their own glacis blended with the latter, and their gorges well secured against surprise. By this arrangement, the evil of their affording an opening through which any revetment can be breached is avoided; and the enemy will, moreover, after he is in possession of the work, be compelled to repeat the most perilous operation of the attack, that of crowning the covert-way.

Hornworks,

When these works are composed of two half bastions and a curtain, they are called hornworks. When their head, composed of a bastion and two half bastions, forms two fronts of fortification, they receive the name of crownworks. When composed of two bastions and two demi-bastions, the name of double crownworks is given to them: it is evident that the addition of another bastion would produce a triple crownwork. But when these works, instead of being terminated by long branches, are connected with the place by their extreme fronts, which not only defend themselves but are defended by the works of the place, the name of couronnée is given to them. Such are the couronnée of Landau, and that of Yutz at Thionville. The hornwork, if its ditches open into the main ditch, and its branches rest upon the body of the place, unless there be some circumstances of peculiar advantage in its situation, would rather weaken than add to the defence. If its ditches open upon those of the ravelin or other outworks, it may add six or seven days to the siege. It will add twice as many if the work be placed beyond the glacis, as above mentioned. The crownwork, although it has two fronts, adds nothing to the resistance of the part which it covers, if its ditches expose the walls of the latter. If placed upon outworks it may prolong the defence about eight days; and twice as long, if placed beyond the glacis. The double crownwork, as it consists of three fronts upon a straight line, or on a line nearly straight, is capable of a much better defence, and will even add to the resistance of the place, although its ditches should open into that of the latter. This increased resistance may be fairly estimated at eight days, when the ditches open into those of the outworks; and at twice as many when they only open upon the glacis. The couronnée, indeed, as it may be considered in the light of a portion or segment of a fortress, may possibly be stronger than the place itself: this, however, will depend upon the manner in which it is applied. If its ditch is made to open into the main ditch, it will be defective: but this junction is generally so contrived that the trouées or gaps may not enable the enemy to breach through them. In the former case, the only delay will be that required for erecting breaching batteries in spots where they may act through those gaps, and this will but amount to five or six days, which will be doubled if the couronnée rests or is directed upon outworks. In short, the full influence of the couronnée, in adding to the resistance of the works which it covers, will only be felt when it is placed beyond the glacis. The above estimate of the value of the different great exterior works, is that given by Bousmard, in his *Essai Général de Fortification.*

Crownworks,

and Couronnées.

Advanced covert-ways.

If, in consequence of a rivulet passing along the foot of the glacis, the making of sorties from those fronts should become a difficult operation, it is usual to construct, on the other side of the stream, another covert-way performing the same office as the original one. In it are placed the advanced posts to watch the enemy's movements; troops destined to act upon the offensive are assembled there to make their preparations for the attack; and they retreat into this advanced covert-way as into a place of refuge in the event of discomfiture. If the advanced covert-way is situated before a portion of the enceinte, the fronts of which are nearly on a straight line, and if its salients are supported by advanced lunettes, it will give the enemy as much trouble to take it as the original covert-way itself. The place will therefore experience by this addition to its works a sensible advantage: since the besieger, after capturing the advanced covert-way and lunettes, must renew operations upon the inner glacis against the ravelins and their covert-ways. The advanced covert-way, besides affording the lunettes security against a surprise and their salients an immediate defence, renders them more efficient works, and capable of a more protracted resistance than if not so enveloped; and these properties in the advanced covert-way have caused it to be employed as a means of increasing the strength of a place, even in cases where no such necessity existed for occupying ground beyond a rivulet. But these advantages only exist under the particular circumstance of the fronts being developed upon a straight or nearly straight line, with their extremities resting upon natural obstacles. For without these conditions, the advanced covert-way which might surround a fortress altogether, as it would have a developement much greater than the ordinary covert-way, would likewise have branches longer and more liable to the ricochet. To this disadvantage may be joined that of being only defended by the lunettes; as the fire of the place must cease as long as the advanced covert-way is occupied. The great distance between the salients, which should afford each other a reciprocal defence, may also be mentioned as a serious defect. A work of this kind may, therefore, without much difficulty, be carried by storm, and would require the besieger to make but two parallels, and to break ground at a small distance from the salients. From which it appears that the construction of a general advanced covert-way round

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a place, at least when fortified on an inferior polygon, would be productive of no real benefit to the besieged; and the expense would nevertheless be greatly increased. We may therefore (says Dufour) establish as a principle, that an advanced covert-way can only be made before a portion of the enceinte not likely to give it an excess of developement, and that even then care must be taken when constructing it: 1st, That the narrowest space enclosed between the two covert-ways shall not be less than sixty yards wide. 2dly, That every part of its counterscarp shall be revetted; and that this revetment shall be of a nature to force the enemy to make a descent into the ditch, and shall put it out of his power to surprise and storm the lunettes at their gorges. 3dly, That the places of arms be provided with small redoubts in which the defenders of the salients may find a safe retreat. 4thly, That the advanced covert-way be not as high as that which it surrounds, in order that the enemy, when he has reached the crest of the former, may be unable to see into the latter. 5thly, That the faces of the lunettes be always flanked by the salient parts of the ravelins or bastions. It is no easy matter to adhere to all these conditions on a level country; and it can only be done by giving to the covert-way of the place a more than ordinary degree of relief, and by producing its glacis beneath the natural level of the soil, as far as the counterscarp of the advanced covert-way, thereby enabling the latter to have a greater height. The glacis of the advanced covert-way may in a great measure be formed of the earth so excavated. Recourse may be had to this method of lowering the ground by producing the glacis, for the purpose of establishing lunettes of which the gorges shall have sufficient height to prevent escalade, without elevating their crests too much above the level of the country.

Lunettes.

The lunettes above alluded to are a species of ravelin usually placed upon the salients of the covert-way to flank the approaches. Where there is an advanced ditch, the lunettes are placed upon its borders, but where no such ditch exists, they are situated at the foot of the glacis. The lunettes themselves have a ditch twelve or fifteen yards wide, surrounded with a covert-way, to screen their revetment from the enemy's distant batteries and prevent them from being stormed at the gorge. A series of good lunettes judiciously disposed, should afford an excellent defence. It is calculated that such works, on polygons of ordinary size, may add ten or twelve days to the defence, and considerably more when the angle of the polygon is very obtuse. Their advantages are chiefly these: they compel the enemy to break ground at a much greater distance from the place; and as a preliminary siege must be gone through to take them, ere that of the place itself can be said to have commenced, the defence is prolonged by all the time consumed in their attack. These works are, nevertheless only adapted to large fortresses; as they need an employment of troops and artillery beyond the limits of the enceinte, which a numerous garrison alone could afford. If the lunettes are surrounded with a dry ditch, it is absolutely necessary to revet them with masonry: otherwise a few rounds of the enemy's cannon would soon lay waste the fraises or inclined palisades, and they might be assaulted without further trouble. But, where a wet ditch surrounds them, the expense may be spared, as no such danger need be apprehended.

Flèches.

A smaller and much less important work than the lunette is often placed at the foot of the glacis. It is made in form of a redan,* and the name of *flèche* is given to it. The faces of the flèche are usually made twenty-four or twenty-five yards long. Its object is to support and flank an advanced ditch, or advanced covert-way. When the glacis of a place is very steep, and the covert-way of more than ordinary relief, the flèche is of great use, because its fire acts upon spots unseen from the covert-way; but when the latter has but a small relief, the flèche may be omitted, as its relief may obstruct the fire of the covert-way, and enable that of the enemy to plunge into the latter work when he is in possession of the flèche.

Advanced ditches.

When the site of a fortification is low and marshy, and it becomes impossible to give the ditches the necessary depth for furnishing sufficient earth wherewith to construct the covering masses, a second or advanced ditch is excavated at the foot of the glacis, which will make up the deficiency and obviate the necessity of going to a distance to obtain it. Although the advanced ditch serves as an obstacle and prevents the enemy from arriving at the covert-way, it is, nevertheless, far from being a good work when isolated as is the case in many fortresses. For if, on one hand, the enemy experiences a difficulty in getting across it, the besieged, on the other, feels great inconvenience when making sorties, as he must pass over bridges, troublesome to construct and easily demolished by the enemy's distant batteries during the first days of the siege. There are, nevertheless, some advanced ditches possessing great advantages: we allude to such as may be kept dry, and suddenly flooded at the will and pleasure of the besieged. The latter would thereby derive all the benefit resulting from an uninterrupted communication during the early part of the siege; and when the ditch falls into the enemy's hands he may suddenly let the water into it. These cases, however, are rarely met with. If the nature of the localities be such that it is out of the enemy's power to drain the wet advanced ditch by cutting a canal and turning the water into it, the bed of the ditch may be made in any manner whatever. But where the possibility of such a thing is at all a matter of doubt,—and it is impossible to ascertain the fact otherwise than by the nicest levellings,—the slope of the glacis must be produced to form the ditch: in order that the enemy may not find any cover there when he has drained and occupied it. It is impossible to fix the breadth to be given to advanced ditches: it must depend upon their form; the nature of the ground; and the quantity of earth necessary for the construction of the works. But the wider they are the better.

Detached works.

The name of detached works is given to such as are unconnected with the fortifications of the place, either by an advanced covert-way, or in any other manner. The chief object of these works is, to obtain reverse fires upon the enemy's approaches at the time of his attack upon any of the neighbouring fronts: so that he may be under the necessity of reducing the advanced or detached work, ere he can undertake the siege of the place itself. Now the taking of a detached work is any thing but an easy operation, if from the nature of the situation it can in a manner be rendered inaccessible; and this will be the case if it is situated in the midst of

* See *infra*, Field Fortification.

an inundation. Supposing it to be so placed, it will still be well, in order to secure it from surprise by boats or rafts, to surround it with a covert-way or dike, separated from the work itself by a wide and deep ditch. Those parts of the work which are to afford the reverse fires above alluded to, should be so constructed as to be screened from the ricochet fire of the enemy's batteries; and the detached work should be placed at a distance of one hundred and fifty, or one hundred and sixty yards, from the edge of the inundation, to be beyond the range of the mortars used for throwing stones or small balls. Its parapet should, moreover, be twenty-four feet thick, to render its demolition a matter of greater difficulty to the besiegers.

Besides ground of such a nature as will admit of being inundated, there are many other situations in which a detached work may be rendered inaccessible to the enemy; or at least, in which he shall be compelled to the developement of extraordinary means ere he can hope to reduce it. When placed upon a steep rock, too hard to be either breached or mined and too elevated for the escalade, it may be considered inaccessible; and it would, moreover, have the advantage of commanding reverse and plunging fires, from which nothing within a considerable distance could escape. A detached work may likewise be deemed inaccessible when built upon an extent of flat bare rock, on which the enemy could neither dig trenches nor sink shafts of mines; and the difficulty of reducing it will be greater, if care has been taken during the leisure of peace to establish underneath its glacis, by dint of labour and blasting, a good system of defensive mines. The bastion fort of La Lippe, at Elvas, in Portugal, is of this nature; as are likewise the detached works at Luxembourg: both of which are worthy of being studied by professional men.

It is not, however, always possible to find situations which almost of themselves shall render a detached work inaccessible: it will therefore be necessary to compensate for any local disadvantage by creating all the artificial obstacles that can be raised. In the first place, the work should be revetted with masonry both at the escarp and counterscarp. The former should be at least fifteen feet high, and crowned at top with a row of inclined palisades as a security against escalade. Behind the revetment of the gorge (if the work be in the form of a lunette) a loop-holed gallery should be made, having the crown of its vault on a level with the natural ground: in order that it may be secured from destruction by shells. The loop-holes should be as low as possible, that the fire from thence may be more effective, and that the enemy may be less able to fire through them into the gallery. But the most powerful way of adding to the strength of such works is unquestionably that of subterraneous fortification.

In almost every case the position of a detached piece is determined by the localities of the ground, by the nature of the defences of the place, and by the particular object of the work itself. If the latter be intended to have a reverse fire upon the neighbouring fronts, it may require to be placed on such elevated spots as command a view of the acclivities leading to those fronts. If, on the other hand, the object be to see into the bottom of a valley, a site must be chosen for the work at the beginning of that valley. When, in order to fulfil any of these conditions, the work is necessarily placed too far from those of the fortress to derive from the latter a musketry defence, another or intermediate work must be thrown up halfway between them to render it that service. And as this intermediate work is defended by a close fire from the place, and protected against the first fury of the enemy's attacks by the work in advance, under the fire of which he must pass to arrive at it, it need be but a simple flêche, or at most a small lunette. To prevent, however, its falling by the same attack which might be directed upon the gorge of the detached work, it is necessary to palisade its escarp and counterscarp, and to close the gorge with a strong loop-holed palanque.

There may be cases in which, from the nature of the ground, the detached work will not suffice to fulfil the object in view. For instance, when the elevated ground on which it is to stand, is too broad to enable both its sides to be sufficiently discovered by the work. It then becomes necessary to construct two or more works of the kind; or as many, in fact, as shall completely occupy the whole plateau, and have a good reverse view of the ground by which the enemy must approach to the neighbouring fronts of the place. It, in short, is preferable to occupy the plateau by a series of detached works, rather than to enclose it with one great exterior work. For these isolated works, having in rear of their gorges an open space where bodies of troops may conveniently assemble for sorties, and from whence they may proceed without the embarrassment and delay of filing through the barriers of a covert-way, offer greater advantages for those important enterprises than can a continuous exterior work. The retreat into the latter, when the sortie has effected or lost its purpose, is also slow and troublesome: whereas the intervals between detached works are so many broad and safe passages, through which the troops may speedily retire under the protection of the fire of those works.

CHAPTER IV.

Inundations.

Inundations.

One powerful means of adding to the value of fortresses consists in the employment of water in inundating the adjacent country to a vast extent, and in producing in the ditches of the place such sudden and violent torrents that the enemy's works shall with great difficulty be able to resist their impetuosity. The first effect of a bank thrown across a river, is to produce on the flood side an inundation which will be more extensive in proportion as the dike or dam is high, and the slope of the surrounding ground gentle. By this means the fronts of fortification on the flood side will be in a great measure covered and rendered inaccessible; thereby leaving to the enemy the only remaining alternative of attacking either the fronts on the ebb side, or those lying intermediately. But if, by a sudden removal of the dike, all the water is allowed to rush at once to the ebb side, the river's natural bed being insufficient to contain it, the country must of course be inundated: so that, if the enemy has chosen to attack on that side, his trenches will be swamped and his ammunition destroyed. Hence, when the waters of a river are judiciously managed, the enemy will be forced to avoid its banks both on the upper and lower sides, and to attack the intermediate fronts: upon which a greater expense

in defensive dispositions may be better afforded. Again, it sometimes happens that the waters of an inundation, by rising to a certain height, run off the sides and spread themselves in the country, gradually making the circuit of the town, (either on one or on both sides,) and find their way ultimately into the natural bed of the river. Should the temporary river thus formed be of a good breadth, all the works which it encloses will be protected from the enemy's attacks: but this seldom is the case, as the banks of rivers are usually higher than the dike; and the waters therefore flow over the latter, and continue their course as usual.

The bridge over a river, for communicating from one to another part of the town, is usually converted into a dike by stopping up the arches with sluice-gates: precautions must in this case be taken to prevent the undermining which the fall of the water might produce on the ebb side; and the piers of the bridge ought to be of sufficient strength to be able to resist the pressure of the water. The closing of the arches is, as above mentioned, effected by two sluice-gates, which fall into grooves made in the piers, and are worked by levers or screws in such a manner that they can be quickly and simultaneously uplifted, when it is required, to let loose the torrent upon the enemy's attacks. The besieger, who is usually acquainted with the spot where this contrivance exists, will of course direct against it a great profusion of shells; and it is therefore advisable to have double flood-gates under each arch: so that, if one gets damaged, the remaining one may perform its office. An inundation would also be useless if it were at all in the enemy's power to drain it: that is, to dig a canal into which its waters might be turned. This, however, may sometimes be prevented, by constructing a work near the spot where it is most likely to be done. Such a precaution is more particularly necessary when the drain, in emptying the inundation, might at the same time deprive the place of the water indispensable for the subsistence of the garrison and inhabitants: there being instances of a place surrendering through thirst, which by the nature of its works, and strength of its garrison, might have been expected to stand a long siege.

The advantages resulting from the employment of water as a means of defence do not consist solely in inundating the country about the place. It is likewise in some cases possible to introduce water suddenly into ditches habitually kept dry: whereby all the works, which the besieger may have executed for the purpose of reaching the foot of the breach and facilitating the assault, may be entirely destroyed. When this torrent has subsided, and the smaller rubbish of the breach has been removed by it, leaving only the larger fragments, the breach may be no longer practicable; and the besieger, to render it so, must recommence battering and forming his passage: which—as he will have just reason to apprehend a fresh disaster of the same nature—he must make with the solidity of a real dike capable of resisting the weight of the torrent, and of sufficient height to cause a reflux of the waters. But as all this will require much time and labour, the besieged may leisurely take measures for defending the breach with the utmost obstinacy. The manner, in which these artificial torrents are produced, is as follows. A dike with gates stretches across the river at its entrance into the town, which is generally between two bastions constructed on the opposite sides of the river; and the dike is made high enough to allow the inundation to be six feet above the bottom of the ditch. Then, at or near the place, where the main ditch of the fortress branches out from the river, on the ascending side, gates are formed across the ditch to admit or exclude the water of the inundation; and these, which must be made higher than the dike across the river, to prevent the water from flowing over them, are provided with a bomb-proof cover to secure them from the effect of the enemy's shells. Other gates are formed in like manner at the communication of the ditch of the fortress with the river, on the descending side, and serve to retain the waters in the ditch, or to let them escape, as may be required. The former, for distinction's sake, may be called flood-gates, and the latter ebb-gates.

When the enemy has effected his descent and irruption into the ditch, and has commenced his passage across it, the defenders cease to dispute the passage, and open the flood-gates, leaving the ebb ones closed. The ditch will then fill with water, which, washing down the enemy's epaulement, may compel him to raise his gallery of descent, and commence, in all probability, a fascine bridge, to avoid a repetition of the torrent. This bridge (which is of the lightest kind and moored with small anchors) may have nearly reached the rubbish of the breach, and every preparation may have been taken for the assault; when the besieged, by suddenly opening the lower sluices or ebb-gates, produces a torrent through the ditches which will remove a good portion of the rubbish, and loosen and damage the bridge of fascines. But a still more violent shock is at hand: the upper sluices are thrown open, and the waters rush in with an irresistible impetuosity; carrying away the bridge, and probably discouraging the enemy from any further attempt to overcome so powerful a means of resistance.

A pair of additional sluice-gates may be made somewhere between the two former, to obviate the inconvenience which might result from an accident happening to one of those, and also to augment the force of the current in the ditches on the descending side. The gates are generally placed across the ditch in the direction of the capitals of the bastions, where they are less exposed to the view of the enemy when he has crowned the glacis; and ebb-gates should be made wider than the others: in order that the water may be less retarded in its escape, and any diminution in the force of the current avoided. In order to secure the advantage of using the ditches as dry ones during the first days of the siege; and particularly to afford the means of communicating freely with the exterior works, and of making repeated and vigorous sorties; it is necessary that the bottom of such ditches be about one foot above the ordinary high-water mark in the river. A cunette, or small drain, is dug along the ditches of the place in order to carry off the water, which (even when the gates being closed the great mass of it is excluded) will inevitably filter through the masonry of the dikes. To procure to the currents in the ditches all their desired effect, it is necessary that the sluice-gates be made to open promptly and give a wide entrance to the water. Of all the means as yet proposed, to arrive at this desideratum, the most simple is that contrived by M. de Bousmard, which, although it has never perhaps been tried, is very ingenious, and deserves to be here described. He proposes two piers, with a door between them turning upon a vertical pivot or axis, which is placed so as to divide the door into two unequal parts. The pivot is firmly secured at top by a cross beam or otherwise, and at bottom by a flat stone into which it is

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let. The door being unequally divided, it follows that the stream presses more strongly (the volume of water being greater) on the largest of the wings; and this, as it rests against a groove in the quay or pier, naturally keeps the gate closed, and excludes the water. But on the above-mentioned largest wing there is a small door which can be opened by such machinery as is used in the apparatus of canal locks. The opening of this small door reduces the surface of resistance to less than that presented by the smallest of the wings. The consequence is that the greater pressure being thrown upon the latter wing, the gate turns upon its axis or pivot and gives free ingress to the torrent of water.

CHAPTER V.

Defensive Mines.

Mines.

The Art of mining, as practised in the Ages of Classical Antiquity, appears to have undergone no change for nearly two Centuries after the invention of gunpowder. A Genoese engineer, at the siege of Serezanella, A. D. 1487, was the first who tried to substitute the use of this destructive ingredient for the old method, but did not succeed. The celebrated Pedro Navarra, then a private soldier, who was present at this siege, on being afterwards received into the Spanish service and raised from the ranks, repeated the experiment with as little success at the siege of Cephalonia. Not discouraged by these failures, he tried it again at the attack upon the Castel del Ovo at Naples, A. D. 1501, and acquired, if not the credit of being the inventor, at least that of being the first who had applied this new means with success. Before Bologna, (A. D. 1511,) Navarra again tried his mines, but a singular accident is said to have rendered them abortive: the mines were sprung and the wall was uplifted; but, if the tale may be credited, the whole mass fell again upon its base, offering to the astonished beholders no other proofs of its having quitted its foundation, than the crevices where the separation had been effected! The besieged proclaimed a miracle: but Navarra explained the apparent prodigy, by showing that the charges had been placed with too great precision under the centre of gravity of the masonry.

In order that the reader may the more easily understand the phrases which we shall have occasion to use in the following pages on modern mining, we shall begin by a few definitions. Any subterraneous excavation, made with a view of containing gunpowder for the removal by explosion of the objects on the surface, is called a mine. The place where the powder is deposited is styled the chamber. This chamber is of a cubical form, and of a size proportioned to the magnitude of the intended charge. The excavation produced by the explosion is termed the crater. The line drawn from the centre of the charge to the nearest point upon the surface, whether the latter be upon an horizontal or inclined plane, is technically distinguished as the line of least resistance. The subterraneous roads conducting to the chambers of mines are denominated galleries. These are divided into grand galleries, demi-galleries, and branches. Great galleries are six feet high and three wide in the clear; demi-galleries four feet by three; and the branches three by two and a half. The largest of these galleries may vary in their dimensions according to circumstances: but for reasons which will be explained, it would be improper to alter the dimensions of the branches. The great galleries are the miner's principal roads; and every thing is conveyed through them: the demi-galleries are the communications from one to the other of these roads; and the branches are the small paths which lead from the galleries of communication to the chambers of the mines.

System of permanent defensive mines.

The galleries which usually constitute a simple system of defensive mines are situated as follows. The gallery of the escarp is so called from being situated at the back of the wall which supports the rampart. The object of this gallery is to enable the breach to be more obstinately defended by the explosion of small mines placed under the rubbish at the moment of assault; thereby destroying the assailants, and restoring to the breach its original steepness. It is hardly necessary to say that when this is done, the enemy is compelled to batter the rampart anew. This gallery, moreover, serves to defeat the enemy's attempts to breach by mine, in the event of his preferring that means to battering with cannon, or if he should be disposed to employ both. With respect to dimensions, this gallery of the escarp is of the largest above mentioned; and its situation is shown both in the plan and profile. See pl. iv. fig. 2 and 3.

Another gallery extending along and underneath the covert-way is called the counterscarp gallery. Its situation has been considerably varied according to the opinions of the different contrivers of Systems. Some have placed it underneath the banquette of the covert-way; some under the middle of the terreplein; and others again close behind the counterscarp wall. The latter disposition seems to be more generally preferred, as most economical, most easily lighted and aired, and furthest removed from the influence of the enemy's explosions. The lighting and airing here meant are obtained by loopholes cut in the revetment of the counterscarp which, besides, enable a reverse fire to be had upon the enemy when he may have penetrated into the ditch: the entrances into this gallery are provided with stout oaken doors with bolts on the inside. Many authors, however, object to this situation for the counterscarp gallery: alleging that, when the enemy has possessed himself of it, the very contrivance for affording a reverse fire along the ditch, will serve him to keep in check any sorties which the defenders may make to dispute his sap or passage across the latter. The entrances into this gallery are most frequently made in the counterscarp wall near the re-entering angles of the latter; and, in that case, a tambour is made upon the terreplein of the covert-way enclosing the stairs at the re-entering angle. This measure of security is, however, unnecessary when the re-entering places of arms are (as in the modern and Cormontaingne's Systems) provided with a redoubt. Besides this precaution, it is well to have a caponnière on each side of the entrances, to flank the accesses to them along the main ditch and that of the ravelin. When the soil is dry enough to admit of it, the safest way of communicating into the counterscarp gallery is by a gallery of communication passing from that of the escarp underneath the ditch. This procures, moreover, the advantage of enabling a branch to be driven from it under any spot where the enemy may be making his passage across the ditch: besides affording security against any attempt to seize upon the galleries by a sudden attack.

A gallery running parallel to that of the counterscarp at a distance of about forty or sixty yards from it—that is, about the distance of the foot of the glacis—is called the envelope. It communicates with the former by others, situated under the ridges and furrows of the glacis, and which are denominated galleries of communication. The gallery of envelope is omitted in most Systems, because, presenting an extensive front to the enemy, it is speedily destroyed by his first explosions; and it is urged that mere passages terminating in a point, or by a portion of envelope, so as to resemble the letter T, are more advantageous: as they not only answer the same purpose of enabling the defender to commence early his dispositions for intimidating the enemy; but the destruction of one portion would not entail that of the neighbouring one, or facilitate the enemy's attempts to introduce himself into the galleries after an explosion. But, in any case, from the envelope there are other galleries extending into the country to a distance of about thirty yards; placed at intervals of fifty yards; and called listening galleries, or listeners, from their object, which is to enable the besieged to anticipate his enemy by watching his approach under ground. The distance to which it is possible to distinguish sounds, must of course depend very much upon the more or less compact nature of the soil: but, in ordinary cases, the blows of the excavating tools may be heard at a distance of thirty yards; and those of the hammer in fixing the framework at forty or fifty. The reason, therefore, for placing the listeners fifty yards asunder, is obviously to render it impossible for the enemy to penetrate between them unheard, either from one side or the other. The means resorted to by the miner of the besieged to assist him in listening, are various. He may lay a plate of sheet iron flat against the side of his gallery, and apply the ear to it. He may drive a trepan hole in the most likely direction, and listen through it; and if he has any reason to apprehend that the enemy will attempt to pass under him, a pea, or any round body, placed upon a drum head, will vibrate at the blows of the pick and betray the design. At certain distances along the whole of these galleries there are ready-made doorways, merely filled up with loose bricks. These are also called listeners, as they serve for that purpose, and enable the defenders to drive branches, without loss of time, in any particular direction. To prevent the enemy from obtaining possession of the whole of the galleries in the event of his succeeding in getting into a portion of one, care is taken to partition them off with strong oaken doors, having loopholes with shutters in them, through which a fire may be directed against the besieger, or stink balls thrown to smother him. The galleries of communication are likewise separated from the principal galleries by doors of the same material; but these slide back into a groove in the wall, instead of turning on a hinge, which from the nature of their situation would be inconvenient.

Listening galleries.

It often happens that no system of defensive mines has beforehand been made underneath certain fronts of a fortress, which nevertheless may require such an expedient: in order to establish an equilibrium of strength between them and the remaining fronts. The manner in which the establishment of such mines is effected at a moment when a siege is anticipated, remains to be described before any thing is said respecting the charges of mines. The first thing done is to determine, upon the plan of the works, the situations which it may be most expedient to allot to the several galleries. It is unnecessary to observe that, here care must be taken not to run into useless expense and loss of time, for the mere sake of symmetry. The galleries must be made underneath those spots upon which the enemy is obliged to conduct his saps; and it would be needless to drive them in places where, being seen in reverse by some projecting outwork, he would never attempt to approach. When these points are settled, the plan thus devised upon paper is marked out upon the surface of the ground, and at all the intersections of the lines denoting the situations of the intended galleries, shafts are sunk. The reason for sinking shafts at the intersections is, that any inaccuracy of direction in the driving of the galleries may thus be the more easily corrected: as, when the shafts have arrived at the required depth, the galleries are driven from thence to meet one another between every two shafts.

The materials used for sinking the shafts are square or oblong frames, with a sheeting of planks to prevent the earth from falling in. The operation is commenced by placing one of the above frames (with projecting ends of a foot or fifteen inches length) flat upon the ground, with two of its sides at right angles with the line denoting the direction of the intended gallery. The frame is fixed so as to be immovable; with pickets or stakes driven in on each side of the projecting ends. The miners now commence digging; and the depth of the excavation must depend upon the greater or less tenacity of the soil. In ordinary soil, the second shaft frame may be placed at a depth of four feet. When, therefore, the miner has dug to this depth, he makes the bottom of the shaft perfectly even and level, and then places the second frame (of course without projecting ends) vertically under the first, and ascertains its position with a plumb line. This done, he connects the first frame with the second by means of wooden ties of equal length, nailed to the centres of the sides of the frames. The sheeting is then introduced between the frames and the earth; and wedges are placed between the sheeting and the second frame to preserve room for slipping in the planks from the second to the third. Any cavities between the earth and planking are filled up with sods or sand-bags: in order that the sheeting may press firmly against the frames. The digging is now recommenced and continued to the same depth: when the framing, sheeting, and adjusting are repeated. As long as the excavation is sufficiently near the surface, the loosened earth is easily thrown up by manual force; but in proportion as the shaft becomes deeper, other means are resorted to for its removal. A cylinder, turned by a winch, like the machine used for drawing water out of a well, answers the purpose sufficiently, by passing several times round the cylinder a rope having a basket or bucket fastened to each of its ends: by which means one ascends loaded whilst the other descends to be filled. When the shaft is sunk to its required depth, the sides of the two last shaft frames, situated in the direction of the intended gallery, are removed; and the excavation of the latter is commenced, either horizontally, or with the inclination suited to the object in view.

Pl. iv. fig. 4.

In the driving of galleries, the means of keeping up the earth are much the same as those employed in sinking shafts; frames and sheeting being employed for the purpose. The former of these are composed of two stanchions, a capsill, and a groundsill; the latter is sometimes omitted, but such a practice is not to be recom-

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mended. There are, however, many cases where sheeting is not altogether indispensable; as when the soil is sufficiently stiff to support itself without such assistance. The frames by themselves are then used; and even these are often dispensed with, in strong soils, and where the mines are intended for immediate use; it is nevertheless scarcely justifiable to put men's lives into jeopardy, merely to economize a few pieces of timber, or the few additional moments which the fixing of the latter might require. When these galleries are made, as here supposed, at a moment of need, it will suffice, in order to save trouble, to give them four feet and a half of height, by three, or two feet and a half, of width. When a branch only is driven from one of the above galleries to the place where the powder is to be deposited, it may be made three feet high, by two and a half broad: there is nothing gained, with respect to time, by making it smaller; for if, on one hand, there is less to excavate, on the other, the inconvenient posture of the miner, who even in a gallery of the above dimensions is obliged to work sitting, will render the progress of the work nearly the same. But there is an important reason for not increasing the dimensions of the branches:—that the smaller they are made, the more readily and solidly may the mine be tamped, and the less likely will it be, that any part of the charge should find vent along the branch. The earth is removed from these branches by means of a small four-trucked cart, having a cord at each end. In proportion as the first miner excavates, a second draws the earth towards him with a hoe, and fills the little cart; which is then drawn by a third to the entrance of the branch; where the earth is received and transported to a greater distance, or to the foot of the shaft, by a fourth. Four miners thus employed constitute a brigade. When it is necessary to fix the framework, the whole four assemble for the purpose. It has been found, by repeated experiments and by actual service, that brigades of miners, relieving one another at proper periods, can execute on an average eighteen feet length of gallery in twenty-four hours: this supposes, however, that nothing occurs in the way of obstruction from the enemy to cause any delays.

See fig. 5. plate IV.

The distance, at which the frames are placed in the driving of galleries, is determined by the same reasons which regulate the intervals of the shaft-frames. Some soils, as we have already said, are stiff enough not to require these supports: but, again, there are others which are so loose as to oppose almost insurmountable difficulties to the progress of the miner; and there are indeed cases where, the soil being sand or gravel of the loosest kind, no other alternative remains but to cut out the gallery like a ditch, open at top, case up the gallery carefully with sheeting, and then fill in the soil over the top. It must, however, be observed, that a gallery having but one issue cannot properly be driven beyond a certain limit, without inconvenience or danger to the miner; the air, from want of ventilation, not being proper to support life. When, therefore, it is necessary to go beyond that limit, some means must be employed to produce an artificial current of air. The most common expedient is that of a forge bellows placed at the top of the shaft, and having canvass or leathern pipes extending into the gallery or branch.* A trepan hole may likewise be driven, from the ceiling of the gallery up to the surface of the ground, for the same purpose. When a branch has been driven to the required length, a return is made at the end either to the right or left, and the chamber is excavated. The reason for making the chamber in a return is that the mine may be more solidly tamped; and this is done in a manner to be presently described.

The quantity of powder with which the mine is to be charged must of course depend upon the effects required to be produced, and upon the nature and tenacity of the soil in which it is to act. The immense number of experiments made by De Valière enabled him to arrive with great accuracy at the conclusion, that a cubic fathom of soil of ordinary tenacity required ten pounds, ten ounces, six grains of powder to uplift it. Then, on the supposition that the crater of a mine is a paraboloid, having the diameter of its base equal to twice the line of least resistance, and the focus of its generating parabola at the centre of the charge, he calculated the cubical capacity of the excavation in fathoms; and, consequently, multiplying ten pounds, ten ounces, six grains, by that number of fathoms, he obtained the required charge in pounds of powder. In this manner he composed tables, serving to determine the quantity of powder required to charge a mine of the above form, when the line of least resistance is given. Belidor proposes a way of using these tables, as a means of obtaining much more extensive effects than those for which they are exclusively calculated. He supposes that the earth, upon the explosion of a mine, is compressed to an equal distance in every direction from the centre of the charge; and to the extent so acted upon by the ignited mass, he gives the name of a globe of compression. He considers the line drawn from the centre of the charge to the edge of the crater, which is the hypothenuse of a right-angled triangle, having the line of least resistance, and the semidiameter of the crater for the other two sides, as the radius of the globe of compression. Then, he says, globes of compression, like all other globes, are to each other as the cubes of their diameters or of their radii. If, therefore, instead of a crater whose diameter is equal to only twice the line of least resistance, (as estimated in De Valière's tables,) it be required to form one in which the diameter shall bear a higher ratio to that line, it is only necessary to add together the squares of the line of least resistance in the tables and the semidiameter of the crater, to obtain the square of the hypothenuse of that triangle: or, in other words, the square of the radius of the globe of compression which would be formed with the charge in the tables corresponding to that line of least resistance. Find in the same manner the square of the radius of the required globe; extract the square root from each; then cube them; and, by proportion, the cube of the former radius is to that of the latter, as the charge in the tables is to that, which would be required to produce a mine having the given dimensions.

The practical application of the rules above given, and indeed of any others as yet proposed, is however very limited; the effect produced in different soils by fired gunpowder bearing no constant proportion to the amount of the charge, and the error becoming very considerable when the charge is great. Experience also has shown that no quantity of powder will make a crater larger in diameter than about six times the line of least resistance; and that the diameter of the globe of compression in that case will not exceed about eight

* But a much preferable machine, resembling the hydrostatic bellows, with a very simple and convenient apparatus of pipes, has been introduced for the same purpose into the British service.

times that line. The case would be different, and effects would be always nearly in proportion with the magnitude of the charge, were it possible that the whole of the powder should become ignited at the same instant: this, however, cannot occur, as its particles ignite successively, and the portion first fired blowing up the earth above it, allows a certain quantity to escape through the fissures, either unfired or without producing any useful effect. The rule given by Belidor for determining the charge of a mine where the maximum of the effects of powder is required to be produced, the line of least resistance being given, is this: multiply that line, in feet, by 300, and the produce will be the required charge in pounds of powder. But the quantity of powder, thus obtained, much exceeds that which would have resulted from the employment of the formula before stated. The magnitudes of mines are now commonly expressed by the number of times the line of least resistance is contained in the diameter of the crater: thus a mine is said to be one lined, two lined, three lined, &c. according as the said line is equal to once, twice, three times, &c. the diameter; and from experiments recently made in this Country it has been determined that, in earth of medium tenacity, the charge, in pounds, may be found by multiplying the cube of the line of least resistance, in feet, by 0.033 for a one lined mine, by 0.095 for a two lined mine, by 0.21 for a three lined mine, &c.; and these numbers are nearly proportional to the squares of the diameters of the craters, when the lines of least resistance are equal. It has been also found that, when it is intended to destroy a solid mass of masonry by placing powder within it, the charge in pounds should be equal to about one-tenth of the line of least resistance.

The charge being ascertained, the chamber is excavated of the required dimensions, and a box of a cubical shape is prepared for containing the powder. If the ground be at all damp, it is necessary to calk and tar this box, the size of which must be such as to contain, as exactly as possible, the proposed charge. This, as well as the size of the chamber, may be determined by considering that a box, of which the capacity is equal to one cubic foot, will contain 57.6 pounds of powder. With respect to shape, the spherical would be better for the purpose than the cubical for obvious reasons; but the difficulty of making spherical boxes renders it necessary to adhere to the other form. The foot cube, abovementioned, is the inside dimension. If, therefore, for instance, it were required to make a box to contain a charge for four hundred and sixty pounds, it is evident that its interior capacity must be equal to eight cubic feet, or that the box must measure two feet every way on the inside. Inch planks will suffice for the timber of the box. Every thing being ready for charging the mine, the box is placed in the chamber, and being firmly fixed, a wooden trough reaching to its centre is introduced into it, through a square hole made for the purpose in the side next the branch. This trough is destined to contain the canvass powder-pipe or hose, by which the fire is communicated to the charge. The size of the trough should be about an inch square inside. With respect to length, it is continued as far as the spot where the fire is to be communicated, and it is made with such bends and angles as may be necessary. When the box is fixed and the trough is adjusted, the latter is nailed to the ground-sills of the branch frames to secure it from any movement. The

See fig. 7. plate iv.

powder-hose is then laid in it, with its end in the centre of the box, and with a peg driven through it to prevent the possibility of its recoiling. The lid of the trough is now nailed down, and covered with about one foot of earth, taking care at the same time to guard from damp or fire the outer extremity of the hose. This done, the powder of the charge is conveyed into the box in leathern bags, which the miners pass from one to the other, and which are emptied by the last into the box. When the latter is full, the lid is fastened down, and any vacant space about the box is filled up with sand-bags and rubbish strongly rammed. There is then placed up, against the box and the space thus filled, (as shown in fig. 6, which represents a vertical section through the branch and chamber,) a partition of strong planks firmly butted against the opposite side of the branch, where other planks have been put to strengthen the abutment. The interval between the bracing beams is filled up with sand-bags, and every thing which comes to hand; this wadding up or tamping, as it is called, is continued in the branch to a length equal to once and a half the line of least resistance; without which the mine might partly vent itself in that direction.

Now the greatest inconvenience experienced in the use of mines arises from the smoke of the powder, which, after the explosion has taken place, penetrates into the branch and neighbouring galleries, corrupting the already stagnant air even to endangering the lives of those who breathe it; in consequence of which the men are compelled to abandon the galleries until, by means of a ventilator,* the air may have been renovated. This has besides the evil of affording the enemy time to dig in the crater and reach the tamping or wadding of the branch without running any risk, since his work is performed in the open air, where a free circulation carries off the deleterious matter. Many have been the means at different times suggested for diminishing this evil: we shall however confine ourselves to that which has been most successful, and which was invented by the Commandant of the military school of Verdun, M. de Rugy. The greatest part of the smoke at the moment of explosion is projected outwards with the earth removed; another portion, which has been unable thus to escape, issues out after the explosion through the rubbish which has fallen back into the crater; and, lastly, a third portion, driven to the bottom of the crater by the rubbish, and being unable to find vent upwards, pours through the trough and fills the branch or gallery. It is not therefore so much the smoke of the charge that is to be apprehended as that of the powder-hose used for springing the mine; the latter smoke being impelled with violence through the trough into the branch immediately after the explosion has taken place. The smoke thus produced by the hose is more than sufficient to prevent the miner from reaching the mouth of the trough, owing to its pestiferous qualities: it is moreover soon joined by that which comes from the explosion of the charge; and the whole united spreads itself through the galleries to an extent greater or less in proportion to the magnitude of the charge and compactness of the soil. It was therefore found necessary by M. de Rugy to abolish the use of the hose; and his contrivance is as follows. In the centre of a small chain he fastens some match, and at each extremity of the chain he ties a small cord or string of a length at

* For a description of this ventilator, see Belidor's Treatise on Mines.

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least equal to that of the trough it will have to pass through. A double instead of a single trough is made to communicate with the charge; and the above chain and strings being laid in it, the lid is fastened down as before. When therefore it is necessary to spring the mine, the match tied to the chain is lighted; and by gradually pulling the string it is drawn over a spot close to the charge, where some loose powder has been strewed, the ignition of which will of course communicate the fire to the mine. The use of the string at the other end of the chain is to enable the latter to be drawn back again in the event of any thing preventing the explosion from taking effect, or of the chain hitching any where on its way. This contrivance has often been found in the highest degree successful: it preserves the branch altogether from smoke, when the tamping has been properly executed, and when care is taken after the springing of the mine to stop up the mouths of the troughs immediately with sand-bags. But it has one objection, which is the great nicety required in making the trough: the inside must be very smooth, the angular parts properly rounded off, and the joints well put together, so that nothing may impede the movement of the little chain. Notwithstanding such difficulties, there is no doubt that this method is preferable to any other, when it is, as is generally the case, desirable to make use of the gallery immediately after explosion.

Before we conclude the present chapter, it may not be inappropriate to mention some precautions which it is necessary to observe, in order to prevent accidents whilst preparing the mine. The men should be obliged to take off their shoes, for fear of the nails which they may have on them. The nails for fastening the lids should be of a different metal from that of which the hammer is made. The powder should be conveyed in leathern pouches instead of sand-bags: lest any grains should get strewed along the ground, and thus form a train which might be productive of the greatest disasters. It is likewise recommended that the sand-bags used for tamping should not be filled up to the top; but that a portion should be left empty, and that the bag be then tied as near the mouth as possible. This, as the soil will lay loose in the bag, will render the filling up of chinks infinitely more easy, and the tamping therefore more compact. Two or more mines placed near one another may, by springing simultaneously, produce an effect much greater than could be obtained from them when fired one after the other. It may therefore, in some cases, be desirable to effect this joint and simultaneous explosion; and the way to do it is simply to make the hoses of all the charges of equal lengths. If likewise it be wished that one mine shall spring before another, it is only necessary to shorten the hose communicating with it; but no diminution of length need be made to allow for the effects of bendings in the hose, as directed in the works of most French Authors on Mining. For recent experiments in this Country have proved that, so far from burning more slowly, as asserted by those Writers, a bent powder-hose fires with rather greater rapidity than a straight one of equal length. But the real difference in the rate of combustion is too small to require any allowance in practice.*

CHAPTER VI.

Casemates.

Proper situations for casemates.

Though it is probable that, during ages to come, few opportunities will occur for making great improvements in the construction of fortresses; and though there is reason to believe that the means of defending places will never again become equal to those which may be displayed in the attack; yet these considerations should not be allowed to discourage the efforts of military men to give a degree of strength to their works, beyond that which can be afforded by an exact adherence to the Systems already in use. Since whatever can prolong, but for a few days, the defence of a fortress may, in some circumstances, be productive of the most important consequences. With these views, therefore, besides the casemates or covered batteries in the tower-bastions and flanks of the body of the place, which have been described in the Second and Third Systems of Vauban, such batteries have occasionally been formed or proposed in other situations, to cooperate with the artillery on the ramparts for the defence of ditches. It is plain, indeed, that casemated batteries, if confined to their ancient site in the flanks of bastions, must be utterly useless in any other constructions than the Systems above mentioned: since they would be masked by the tenaille which, by covering the curtain and flanks themselves from being breached, serves too important a purpose to be removed. But suggestions for a more general adaptation of casemates have, since the publication of the Systems of Montalembert and Carnot, been offered by French engineers; and it appears that some efforts to reduce these ideas to practice were, during the reign of Napoleon, actually made in the fortifications erected in Italy and at other extremities of the Empire.

Proposals of modern French engineers.

According to the author of the *Analyse de l'Ouvrage intitulé Réflexions Critiques sur l'Art Moderne de Fortifier*, these expedients consisted chiefly in the formation of casemated batteries within the ramparts of fortresses; and in the affording of a more effectual defence to covert-ways, with security against the ricochet fire of the enemy, by means of loop-holed galleries. On the faces of bastions or ravelins, where it is of importance to direct a powerful fire upon the works of the enemy, it was proposed to raise the rampart to a considerable height: but this, instead of being a mere mass of earth, was to consist of two or more tiers of strong and well-ventilated casemates; formed with masonry along the whole face; and having embrasures in the manner of port-holes towards the front. Each tier of casemates was to recede from that below it, according to the nature of the exterior slope of the rampart: so that, though the lower tier should be ruined by the enemy's artillery, the upper would not fall until the side walls should be demolished far within the face of the work. Behind these casemates it was proposed to have a vaulted gallery for the passage of guns, ammunition, &c., under cover along the rampart; and, on the opposite side of the gallery, to have other casemates for troops, stores, &c. Into these, also, was to be finally withdrawn the artillery of the anterior casemates; so that the fire might from thence be continued even after the latter should be destroyed. Over

* Almost all the details which belong to the processes of Military Mining, have during the last fifteen years, been very much simplified and improved by long practice and repeated experiments, at the school for the instruction of the officers and soldiers of the British Engineer Corps, under Colonel Pasley at Chatham. But the publication of the notes and rules compiled for the service of that admirable establishment has very properly been interdicted; and in preparing the portion of the present Article which relates to Mining, it has therefore been resolved rather to abstain from referring specifically to these latest improvements in the Art, than to make an unauthorized use of the official papers in which they are described.

Fortification.

the upper tier of casemates it was recommended that there should be constructed an ordinary parapet, from whence a fire of musketry and grenades might be directed to the bottom of the ditch. These different tiers of guns would permit the defenders to make a grazing or plunging fire on the approaches of the besiegers, as circumstances might require, and to oppose a quantity at least equal to that which could be brought against them. The artillery, also, being under cover, the effects of enfilade and reverse fires would be rendered null: so as to reduce the enemy to the necessity of employing only those which are direct, or perpendicular to the face of the work; and in the casemates the troops might be securely lodged close to the spots at which their services would be required. The partition walls of the casemates were to be loop-holed, and the gallery of communication secured by barriers at intervals; in order that, in the event of a breach being made in the face of a work, it might be defended on each side by a close fire of musketry from thence; and the Author of the *Analyse* concludes that it would be impossible to assault a place fortified in this manner, until after the whole of one face had been completely destroyed.

Nothwithstanding the benefits acknowledged to be derived from the covert-way, by the facilities which it affords to the communications about the works, many serious objections have been urged against it, chiefly on the ground of its exposure to the ricochet, which the traverses very imperfectly prevent: while the steep counterscarp has also been considered as objectionable; by reason of the impediment which it creates to the free movements of troops, when it may be necessary to send them from the body of the place to any part of the covert-way menaced by the enemy. On these accounts some modern engineers have proposed to dispense entirely with the covert-way, substituting for the counterscarp an inclined plane gently descending to the level of the bottom of the ditch; and even those who advocate the preservation of the covert-way, have recommended a formation of this part of the works different in some respects from that which has been hitherto practised.

Description of Napoleon's fortress of Alessandria.

The particular kind of covert-way here alluded to was executed before the works at Alessandria in Italy; a place which, during the reign of Napoleon, was fortified according to a plan given by General Chasseloup de Laubât. Alessandria is situated between the rivers Bormida and Tanaro, which, permitting inundations to be formed, render it in a great degree inaccessible. The town itself, which is of an irregular form, was surrounded by an enceinte consisting of bastions and curtains, but without ravelins. The ancient citadel, however, which was hexagonal, had those outworks; its bastions were constructed with orillons; and both these and the ravelins were covered with counterguards. About the whole, and surrounded by the waters, were disposed nine horn or crown works, each consisting of two or more bastions, but without ravelins; a covert-way and glacis extended along the counterscarp of the ditch; and, beyond these, was an advanced lunette retrenched by a redoubt and protected by its own covert-way. All these covert-ways were without traverses; but, for the purpose of concentrating a great quantity of fire on the capitals, the interior of the glacis on the longer branches was cut *en cremaillère*. The re-entering and salient places of arms were retrenched by redoubts; and those in the latter were of a polygonal form, and having the crest of the glacis carried round them parallel to each face: by which construction several advantages were obtained. For, the fires might be directed at pleasure with considerable efficacy, to any required part of the sectoral space about each place of arms, and might command in reverse the approaches of the enemy towards the re-entering works: while the same places of arms might be powerfully defended by the crossing fires from the latter; and the redoubts themselves (which, from their situation, were not liable to mask the fires from the principal works) were intended, by their elevation, to prevent the ricochet fire of the enemy from taking effect on the branches of the covert-way. Palisades, which have been hitherto considered as indispensable for protection against a sudden assault of the enemy, were here omitted: it being considered that the covert-way would without them be sufficiently defended by loop-holed galleries, which were formed for the purpose behind the escarps of the interior works. These costly and extensive fortifications were subsequently destroyed by the Austrian Government.

PART IV.

DESCRIPTION OF THE OPERATIONS OF A MODERN SIEGE; WITH RESPECT BOTH TO THE ATTACK AND DEFENCE.

CHAPTER I.

Progress of the Modern Art of Attack.

A general outline of the manner in which the Ancients attacked and defended their fortresses has already been given; and it may be observed that nearly the same processes continued to be employed, until the invention and use of cannon caused a thorough revolution in the Art of Sieges. We shall now endeavour, as well as our limits will permit, to follow the subsequent course of improvement in the methods of attack, down to the present times; and it will form the chief object of this rapid sketch, to trace the means by which the superiority, anciently experienced and until a late period preserved, in the resources of defence, seems at length to have been completely and irrecoverably reversed.

Long retention of the ancient course of attack.

During the XIVth and XVth Centuries, as the walls of ancient fortresses had for the most part undergone no alteration, and were consequently discoverable to their very bases from a great distance, little more was necessary than to establish batteries at four or five hundred yards from the place, and to employ them in breaching: whilst a trench was dug in a zig-zag direction towards the broken part of the rampart, in order to serve as a covered road for the troops in rushing to the assault. This mode of attack is practised even at pre-

Fortification. sent, when the walls of a place are considerably exposed. But when, by an improved disposition of the defensive works, and a due regulation of their reliefs, the walls were nearly hidden from the sight of the besiegers, the latter were of necessity compelled to bring their guns to the very counterscarp, in order to see the wall low enough down for effecting a practicable breach. The defence now gained an advantage over the attack; but it was merely momentary. The Art of gunnery made great progress towards perfection; and, when employed in the attack of fortresses, nothing is now found capable of resisting the overwhelming force of the modern artillery. Up to about the middle of the XVIth Century, no regular system of conducting the trenches, by which the fortifications were approached, seems to have been followed; neither were sufficient precautions taken for protecting the saps in proportion as they advanced. It therefore followed that considerable loss of time and of men's lives resulted to the besiegers from the success which attended the sorties from the garrison: who continually harassed the heads of the saps both by day and night, driving the workmen from the unfinished trenches, filling in the excavations, setting fire to the gabions, &c., and carrying off the intrenching tools. At the siege of Thionville, A. D. 1558, Montluc* assumes great credit to himself for having first suggested the means of obviating this evil: he tells us that he made at the end of each zig-zag a little offset trench to the right or left, and placed troops in it to fire upon any sorties that might attempt to disturb the workmen at the head of the sap. But this expedient was long employed in too limited a degree to prevent the frequent recurrence of such interruptions: until, at the siege of Maestricht, A. D. 1673, Vauban being fully empowered to conduct the attack according to his own judgment, abandoned altogether the old routine; and taking, it is said, a hint from the operations of the Turks before Candia,—where being compelled to advance with the utmost circumspection over a vigorously disputed ground, the Ottoman engineers had covered their advance with trenches in every direction—he traced his zig-zags across the three capitals of the front selected for the attack, and supported them at proper intervals by places of arms or trenches of sufficient extent to envelope the whole of the works against which his approaches were conducted.

Invention of places of arms in the trenches; of parallels; and of ricochet fires.

Hitherto the batteries of the besiegers had been thrown up in directions parallel to the line of rampart, the artillery of which they were destined to silence by a direct fire. The accomplishment of this end was, therefore, slow and difficult: as the assailants were under the disadvantage of opposing breastworks of loose soil to the well-settled parapets of the fortress. The only means which they had of silencing or dismounting the artillery of the place was by bringing down the parapets by the mass, and thereby depriving the guns of cover. But before this effect could be produced, their own batteries were repeatedly levelled; and hence sieges were of much longer duration and attended with far greater waste of lives, than after the introduction of a new mode of placing the siege batteries: of which we are now to give some account. It was at the siege of Philipbourg, A. D. 1688, that Vauban, who had for some time fully observed the disadvantage of placing the artillery in the manner above mentioned, determined to try the effect of erecting his batteries at right angles with the prolongations of the faces of the works; and of so regulating the charge and elevation of his guns, that the shot should sweep the whole length of the rampart with frequent bounds, dismounting the guns, and compelling the defenders to quit the parapet. This mode of firing, which is called *à ricochet*, was found very successful. *On ne chargeoit les pièces de ces batteries qu'à demi charge*, says the Journal of the siege, *ou à un quart de charge; et on les pointoit tout le long du chemin couvert des branches de l'ouvrage à corne et de celui à couronne. Les boulets, en effleurant les palissades et labourant la terre, faisoient plusieurs bonds; et alloient se perdre, en sautant jusque dans les chemins couverts et dans les ouvrages détachés du corps de place sur le front de la grande attaque. Ces sortes de batteries ont plus incommodé les ennemis que toutes les autres.* A few years afterwards, at the siege of Ath, (A. D. 1697,) the advantage of this new mode of firing was more fully seen, and its success more complete: for that fortress, of Vauban's own construction and regarded as his master-piece, was besieged and captured by him, after only thirteen days of open trenches, and with the trifling loss of two officers and fifty men killed, eight officers and one hundred and forty-two men wounded. The total expense incurred in the siege amounted to no more than £3570. The Art of Defence may be said to have never recovered from the inferiority, into which it fell in consequence of this change in the employment of the artillery. From this period we may date the decided superiority of the Attack; and there is little hazard in predicting that this superiority will even yet increase: unless expedients be found for covering the artillery of fortresses from the destructive ricochet, and the no less destructive fire of mortars; of which the use is now so much multiplied, and the service conducted with such astonishing precision.

CHAPTER II.

Preparations for a Siege.

Investment.

When the siege of a place is decided upon, the first step taken is to make the investment: which consists in seizing suddenly upon all the avenues to the place; carrying off every one and every thing which, by the negligence of the garrison, may be found outside the walls; and cutting off all communication with the exterior. The works of the place and the surrounding country are then carefully reconnoitred; and a correct plan made of them, if the besiegers indeed should not be already provided with one. The besieging corps are encamped beyond the range of the cannon of the fortress, in situations best adapted to the troops of each particular arm.

Lines of circumvallation and contervallation. See plate iii. fig. 1.

Lines of circumvallation and countervallation to cover these encampments are now so little resorted to, that we shall confine ourselves to the mere explanation of their nature; and it is here sufficient to observe that, generally speaking, they may be omitted in sieges, and a few forts or redoubts substituted for them in commanding situations. In modern warfare, each of these lines consists of a chain of redans, lunettes, or other works constructed at small distances from each other round the fortress, and generally connected by curtains either straight or broken. Lines of circumvallation are those which, facing towards the country, are intended as

* *Commentaires de Montluc*, lib. iv. ad A. D. 1558.

a cover from the attempts of the enemy's movable forces to disturb the operations of attack and relieve the place; and lines of countervallation are made within the above, at a convenient distance facing the fortress, to check the enterprises of a strong and spirited garrison. The finest example that can be cited of the utility of these lines, is the successful defence made by Cæsar within his intrenchments before Alesia, although attacked in front and rear by two armies, each more numerous than his own. But the suppression of these lines simplifies considerably the operations of a siege; though it would be imprudent to proscribe them altogether: since cases may arise to render their employment an unavoidable measure. Thus, at the siege of Mantua in Napoleon's first Italian campaigns, the French army was intrenched between works facing both the place and the country: its numerical weakness and other causes rendered the precaution necessary, and the result fully justified it.

Collection of materials.

Previous to commencing the attack, care is taken to provide in the neighbouring woods or forests the materials necessary for the construction of the trenches; *viz.* fascines, gabions, pickets, sap-faggots, and hurdles. Fascines are bundles about a foot in diameter, composed of the smaller branches of trees, bound together at intervals with twigs. They are of different kinds: the smallest are six feet long, and are used for tracing out the trenches on the ground; the larger kinds, which are frequently called *saucissons,* are twelve feet or eighteen feet long, and serve to revet the slopes of batteries. Gabions are cylindrical baskets open at both ends: the stakes, round which the twigs are woven, being allowed to project a few inches beyond the basket-work at both ends; so that, in placing them, the undermost ends are driven into the ground, and on the uppermost may be fastened fascines to augment the height and solidity of the work. The gabions used in sieges are rather smaller than those employed in other field works: they are here generally about eighteen inches wide and two feet and a half high, and weigh from thirty to thirty-five pounds. Pickets are made three feet long and sharp at one end. Three of these were deemed necessary per fascine. Sap-faggots are bundles of strong branches placed very close together, strongly tied in two places; and then sawed to a length of about thirty inches. The diameter of a faggot is from eight to ten inches; and a picket or stake three feet long is placed in the middle for the purpose of fixing it upright wherever it may be necessary. These faggots were used to close up the interval between two contiguous gabions; but sand-bags are now preferred for this purpose. The hurdles are woven on eight stakes, which form the skeleton. Their dimensions are usually six feet by three. Besides the above-mentioned stores, a quantity of sand-bags are prepared beforehand by the engineer department, and are filled at the moment they are required for crowning the parapets, or for other purposes. All those stores are accumulated in one or more places conveniently situated with respect to the attacks, and which are called the depôts. The judicious choice of the spots to be occupied by the artillery and engineer parks is by no means unimportant. They should be so situated as to permit ready and easy communications between them and the trenches. They should be near water for the convenience of the cattle, and as much as possible screened by distance or rising ground from the fire of the garrison.

In now proceeding to describe the operations of the siege, we shall suppose them to be conducted against a place fortified in Vauban's original manner; and that the front of attack consists merely of two bastions and an intervening ravelin. This supposition is made for two reasons: 1st, because it is the simplest way by which a general idea of the manner of conducting sieges can be conveyed; and 2dly, because there are more fortresses in existence constructed upon Vauban's First System than upon any other outline. We shall likewise, in order to avoid intricacies altogether foreign to our object, suppose the ground over which the operations are carried on to be a level plain. These preliminaries being settled, it will be proper, previously to breaking ground, to state what measures should be taken within a fortress, when threatened with a siege.

Precautionary duties of a Governor.

If the siege of a place is one of the most important operations in war and requires the greatest possible talent in the Generals intrusted with its conduct, it may easily be conceived that, to resist a well-conducted siege, requires still greater ability, experience, and cool intrepidity. Some imperfect idea of the duties involved in the defence of a place, may perhaps be formed from the following details.

An officer who is sent to take the command of a fortress, is bound to make himself acquainted with every circumstance essential to its defence. 1st, He reconnoitres personally all the ground over which an enemy may conduct his approaches; and weighs the advantages and disadvantages of each spot, so that he may act accordingly at a fit moment, and profit by every favourable opportunity of making sorties. 2dly, He carefully examines the advantages and defects of all the fortifications, in order to turn the former to the best account, and remedy the latter as far as may be possible. 3dly, He makes the necessary requisitions for completing the garrison in stores of every description, and endeavours to have an adequate number of troops of the different arms. 4thly, He prepares a proper distribution of his artillery, and causes tables to be made of the distances of all the points about the place. 5thly, From the moment at which the fortress is declared to be in a state of siege, both his powers and duties acquire new extent: the civil authorities are subordinate to him; secret intelligence and espionage without; a severe police within; civil and military administrations, finances, the works of the defence, the service of the artillery, the distribution of the troops, the employment of the inhabitants in extinguishing conflagrations, and the means of repressing popular commotions; all these important cares are his. The issue and expenditure of provisions and ammunition demand the strictest attention in order to prevent abuses arising from negligence or cupidity. And it is likewise important to keep the state of the provisions a profound secret previous to, and during the siege, for reasons too obvious to require mentioning.

Meanwhile the parapets, banquettes, platforms of guns, &c. are repaired; every thing is done to facilitate communication with the outworks; great quantities of fascines, gabions, and sand-bags are made and laid in store. The inundations, where ground permits them, are also now formed. Telegraphs may be constructed, and signals concerted. Every object within one thousand or one thousand two hundred yards of the place, that could afford cover to the enemy, is levelled with the ground; and every possible difficulty is opposed to the completion of the investment. Detachments of expert marksmen are stationed in ambuscade by day and night, as far as six hundred yards from the place, to cut off any

Fortification.

persons employed in reconnoitring. Whilst the besiegers are encamping and marking their first dispositions, every attempt is made to penetrate their views as to the front which they mean to attack. Care is taken to watch from the church steeples where they appear to be fixing their park of artillery: that once ascertained, the rest can be nearly guessed. From this moment a sufficient proportion of cannon is concentrated upon the front attacked; and the service of the garrison is organized: it is divided into three bodies, one of which reposes, another remains in readiness to act, and the third is on immediate duty. The measures to be taken by the Governor of a place might of themselves fill volumes: but we have said as much as our limits justify; and we will therefore proceed to the operations of the besiegers.

CHAPTER III.

Operations of a Siege.

Attack.

Every thing being in readiness for breaking ground, a working party, regulated in respect of numbers according to the extent of the intended parallel and communications, parades at night-fall at the depôt. These men are provided with intrenching tools (spades and pick-axes) and fascines. They are marched to the ground, preceded by an armed force, called the covering party. When they have reached the spot where the engineers have previously marked out (with a white line) the place for the first parallel and the zig-zags, or oblique trenches, communicating from it to the depôt, they are extended along that line, at intervals from each other of six feet, which are marked out for them by the non-commissioned officers. Each workman then lies down upon his belly, to be the less exposed to the fire of the garrison whilst waiting for orders to begin to dig. In the mean while the covering party, drawn up at a convenient distance in front of the parallel, after detaching small parties nearer towards the place to give early intimation of sorties, is likewise ordered to lie down. Every thing being thus arranged, the word is given to begin to work: upon which the men loosen the earth with the utmost possible expedition; throwing it up on the side next the place; and taking care to leave one foot of space between the edge of their excavation and the tracing line. This is to prevent the earth from crumbling into the trench, and the space so left is called the berm. As soon as day begins to dawn, or sooner if the parallel be capable of affording cover, the covering party is withdrawn from its exposed situation into it. Should any light-balls be thrown from the town amidst the workmen, they will endeavour as soon as possible to extinguish them, either by shovelling earth upon them, or covering them with tubs made from commissariat casks sawed in two, a few of which ought to be kept in the depôt ready for the purpose. For a general idea of the dimensions and appearance of parallels, and zig-zags of communication, we refer the reader to fig. 3 and 4. pl. iii., which represent profiles of such works.

Defence.

Meanwhile a good look out from the fortress is kept throughout the day to ascertain where the enemy proposes breaking ground; and as soon as night sets in, light-balls are thrown in every direction to a distance of six hundred yards from the place. From the moment the enemy's design is discovered, the heaviest possible fire is made upon his workmen from the cannon of the place. This may perhaps scare more than do harm: but it will not fail to intimidate the workmen; and a sortie performed rapidly and cleverly by a few dragoons, will, together with the darkness of the night, which magnifies danger, tend to create confusion and delay the progress of the work. There being no longer any doubt as to the front which the enemy has chosen, the works of the defence will forthwith commence accordingly. Traverses will be placed along the terrepleins of the faces, and parados—or covers from reverse fires—on the flanks. Interior retrenchments (if none permanently exist) will be commenced in the bastions and ravelin. Tambours will be made in the re-entering places of arms of the covert-way, and a double palisade on the latter extending along the whole front of attack. If these two last measures be properly taken, it will be out of the enemy's power to possess himself of the covert-way otherwise than by the regular sap; as no hope will remain of his succeeding in attempting it by storm. If the ravelin be a full one, that is, if its terreplein be on a level with that of the rampart, the retrenchment made in it may be in the form of a small ravelin with flanks. But if it be a hollow one, no other retrenchment can be made than a strong tambour of carpentry, with loop-holes in it, covering the communication or retreat in rear. The retrenchments in the bastions, if the latter are full, (and if they are not, it is needless to think of retrenching them,) may be made in the form of a tenaille; or, if there is room, in the form of a small front of fortification extending from shoulder to shoulder, or rather from points on the faces taken at a few yards from the shoulders. These retrenchments are made of earth, revetted with saucissons, and armed with palisades and fraises. Field-pieces and howitzers are brought into the projecting parts of the covert-way to ricocheter the besieger's works. Mortars are placed at the gorges of the bastions, along the curtain and in the ravelins. They may even be placed with advantage in the ditch, when it is a dry one.

Attack.

The oblique communications towards the place now commence; and are driven forward from the first parallel to the intended site of the second. The prolongations of the faces of the works and branches of the covert-way are marked on the first parallel, in order to determine the situations of the ricochet batteries: these batteries, and the particular faces of the bastions and ravelins which are enfiladed by their fire, may be seen in fig. 2. The time occupied in their construction is generally from forty to fifty hours. Two or three large mortars are placed in each of these batteries, to throw shells into the works; by means of which the besieged is kept in continual alarm, and can nowhere find safe cover. It must not be supposed that there is any absolute necessity for fixing the ricochet batteries exactly in the first parallel: they may be planted in any convenient situation upon the prolongations of the works; and it will be attended with no great disadvantage if that situation be not so near the place as the first parallel. At the sieges of Ypres, Fribourg, Mons, Namur, Maestricht, and Gibraltar, they were of necessity constructed at one thousand or one thousand two hundred yards from the works of the place; and they produced, notwithstanding, a very good effect. Recent experiments have, however, shown that the shot from such batteries are most efficacious, when the distance of the latter from the work to be enfiladed does not exceed four hundred yards.

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Light-balls are thrown out from the fortress to enable the gunners to see and fire upon the ricochet batteries whilst constructing; and it may be expedient, in order to retard their completion, to batter one or two of them at a time with a good number of cannon, as, for the reason to be presently given, the besiegers prefer delaying to unmask their batteries until they are all finished and ready to open their fire. If the enemy's guard in the trenches does not appear to be very strong, a grand sortie may be tried. If the case be otherwise, small ones may answer the purpose by frightening away the workmen occasionally, and thus causing their operations to be suspended.

Attack.

The ricochet batteries are finished and unmasked; and the line of aim, the charge, and the elevation of each gun are regulated with such a nicety, that they shall be able to fire by night as well as by day. The unmasking of all the batteries is done at one moment; in order that no particular one should draw upon it an undue proportion of the fire of the garrison, whereby it would soon be utterly destroyed. The communications to the second parallel are continued; but the nearer the place is approached, the greater is the vigilance which should be exercised to anticipate the sorties of the garrison.

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The utmost diligence is now observed in forwarding the works of the defence. The same fire of cannon and mortars is kept up as in the preceding days. The capitals continue to be ricochetted and sorties are undertaken at appropriate moments.

Attack.

The effect of the ricochet batteries is already visible from the diminution of the fire of the place; so that the second parallel may be undertaken at three hundred yards from the crest of the covert-way. The second parallel is to be executed by night, under the protection of troops stationed in short trenches, which are driven out from the angles of the zig-zags, towards the right or left hand, as the case may be; and as the distance from the place is now so much reduced that the fire of musketry and grape may here be fully felt, it is deemed necessary to use gabions for the construction of this parallel, in lieu of fascines: which gives to the profile of the trench, when finished, the appearance exhibited in fig. 3. The operation of digging the trench behind a row of gabions placed openly on the ground is called the flying sap. Some engineers recommend the constructing of a redoubt at each end of the parallel, as a more effectual prevention against being turned by sorties; but it is better to unite the extremities of the two parallels by a trench well defiladed from the place, as shown on the left-hand side of fig. 2.

Defence.

The construction of the second parallel is disputed by every possible means, and the most vivid fire of all arms is directed upon it. Small sorties are made during the night; and towards morning, when the guard of the trenches and the working party are much exhausted with fatigue, a grand sortie of fresh troops is poured out upon them. The firing at daybreak is continued as usual.

The second parallel is at length finished in spite of opposition. The communications forwards are commenced. New zig-zags are marked out and executed to within one hundred and twenty, or one hundred and fifty, yards of the covert-way. At this distance it is found necessary to give additional support to the works of approach; and half-parallels are made for the purpose. Batteries are made at the extremities of these demi-parallels, for containing howitzers wherewith to dismount the artillery of the flanks, sweep the branches of the covert-way, and destroy its palisades. The precautions taken for repelling the sorties will depend upon the energy exhibited by the garrison at this period; but it will be well always to keep on each flank of the trenches, and covered by a breastwork of sufficient height, a body of cavalry ready to cut off the retreat of the enemy, should his zeal lead him far enough in attacking the trenches.

Defence.

In the defence, the same line of conduct is followed as before, counteracting as much as possible every thing done by the besieger. The means of resistance are diligently improved. The damaged parapets are repaired; as are likewise the traverses, palisades, bridges, ramps, &c. that may have received injury from shot or shells.

Attack.

The batteries in the demi-parallels are finished, and their fire is opened. Zig-zags are pushed forward along the capitals. These zig-zags now necessarily become shorter, more frequent, and more oblique, in order to adhere to the condition of avoiding the enfilade fire of the place. The flying sap is no longer practicable; it being impossible, under so close a fire from the covert-way and ramparts, to place the gabions in the uncovered manner hitherto done. A slower but safer expedient is now adopted, called the full or single sap. Its execution, according to the latest practice, is as follows. The sappers employed are told off in brigades of four; and these are numbered first, second, third, and fourth. The first sapper rolls before him a large gabion stuffed full of fascines, to cover him whilst he places a gabion in the line of the intended trench, and fills it by excavating a portion eighteen inches in width and as much in depth. The second sapper, who follows him, widens the trench to three feet two inches without increasing the depth, and continues filling the gabions. The third sapper increases the depth of the trench to three feet, on a breadth of twenty inches, under the part excavated by the second sapper; so that there is left a step eighteen inches in breadth and as much in height on the side of the trench which is next to the line of gabions. The fourth sapper only increases the breadth of the trench by ten inches, but he digs to the depth of three feet from the ground: thus the work of the four men is nearly equal; and cover is more speedily obtained than by the former method of executing this species of sap. When the gabions are full, saucissons are fastened on the top of them to render the work more solid; and the trench is then carried to the necessary breadth by the ordinary working parties of the line. The work of the sap is of so dangerous a nature, that the sappers are frequently relieved; and their exertions are, moreover, stimulated by a pecuniary recompense, which is increased in proportion as the danger becomes greater. The average quantity of this kind of work which can be executed per diem of twenty-four hours is one hundred and sixty yards in length. When the zig-zags have reached the foot of the glacis, a sap is driven to the right and another to the left; and this being done at the head of each zig-zag, the junction of these saps and the extension of the outside ones, as far as to embrace the whole front, will complete the third parallel.

Defence.

This is the most favourable moment for making vigorous sorties, by issuing suddenly from all the branches of the covert-way; to facilitate which, ladders may be placed along the covert-way to enable the troops to pass over the parapet. Every expedient, which the most

Fortification. intelligent genius and intrepid spirit can devise, must be tried to delay the junction of the saps which are to complete the third parallel: for, from the moment that this is effected, all attempts at sorties from any part of the front attacked will be hopeless. A heavy fire of grape is directed upon the heads of the sap.

Attack. As soon as the third parallel is completed, batteries are commenced in it for howitzers, great mortars, and those for throwing stones or one pound balls, wherewith to drive the enemy from the places of arms in the covert-way. By this means all the fire of the place that would obstruct the crowning of the covert-way will be subdued. The batteries in the first parallel may now cease firing, being replaced by those last mentioned. When circumstances render it expedient to storm the covert-way, steps are made in the third parallel on each side of the capitals of the bastion or ravelin attacked, that the troops may be enabled, with greater facility, to pass over the breastwork of the parallel when rushing to the assault. These steps occupy a sufficient length for a company to go over in line. The cases are rare where such a mode of attack is justifiable. The loss which always attends it is incredible. In the attack which we have supposed, it could not be undertaken with the least prospect of success, if the covert-way has been provided with a double palisade. The alternative, therefore, which remains, is the attack of the covert-way by a continuation of the former process. From the third parallel, at thirty yards from each side of the capitals, curvilinear saps are driven forward in such a manner that when they join, they shall form an arc towards the place about sixteen yards beyond the third parallel. (See fig. 2.) From the centre of this circular portion, a double sap is driven straight along the capital to within about thirty-six yards of the crest of the covert-way. This double sap now branches off into two single ones, to the right and left, for the formation of what are termed trench-cavaliers,* or excavations having very elevated parapets, with a view of obtaining a commanding fire of musketry into the covert-way, and driving from it any troops who might dispute its crowning. The reason why this distance is chosen for the trench-cavaliers is, that they may be constructed beyond the range of hand-grenades, which can generally be thrown to about twenty-six yards. The defenders of the covert-way being thus driven from the space comprised between the two foremost traverses, the besiegers hasten to sap up to the salient angle, and then extend their lodgement to the right and left along the whole crest of the covert-way, which the enemy will be obliged to abandon in proportion as the sap advances. The batteries destined to extinguish any remaining fire in the defences are now commenced at the salient angles of the covert-way; (See fig. 2.) these are called counter-batteries. The breaching batteries are likewise undertaken, as is also the descent into the ditch.

Defence. The heaviest possible fire of every kind is kept up upon the heads of saps, and particularly upon the trench-cavaliers whilst constructing. A few oblique embrasures may advantageously be opened in the curtain for this purpose, the effect of which will be greater, owing to the difficulty of ricochetting the guns placed there. Barrels of inflamed combustibles may also be rolled down the glacis upon the heads of saps. When by the crowning of the covert-way, the latter is abandoned, care is taken to destroy the traverses in it, that they may not afford cover to the enemy; and this may be done by exploding some small charges previously lodged in them for the purpose. The enemy's descent into the ditch is anticipated; and oblique embrasures are made at the extremity of the curtain to pour a fire into the opening, which he is about to make into the ditch through the counterscarp wall.

Attack. As soon as the batteries on the crest of the glacis are ready, they begin their work of counter-battering and breaching. Expert marksmen are placed all along the lodgement, to pick off the enemy's gunners, or any one in fact whose head is seen above the parapets or through the embrasures. The descent and opening into the ditch is completed; and a sap is made across the latter (if it be dry) to the foot of the breach. If the ditch is wet, a bridge is made across it by an accumulation of fascines. Now, if the works within were known not to be retrenched, the assault might forthwith be given, should the garrison, upon being summoned, refuse to capitulate; but as the besieged is supposed to have retrenched himself, the sap must be continued up the breach, when the latter has been made quite practicable.

Defence. Meanwhile the sap across the ditch is heavily battered by the besieged. Dispositions are made for an obstinate defence of the breaches, by lining their tops with abattis strongly linked, or by chevaux de frise of sword-blades kept in readiness to be linked together the moment the enemy ceases to fire upon the breach. This was executed by the French at Badajos,* with a success that will be long remembered. Loaded shells are kept ready to roll down upon the assailants, as well as barrels of combustibles. A large fire may be lighted on the breach, and kept up by a continual supply of fascines steeped in pitch or grease. The foremost troops destined to receive the shock of the assailants, are provided besides their ordinary arms with all possible weapons of resistance; and when obliged to cede to the overpowering torrent of fresh assailants, they effect a retreat in good order to their retrenchments; behind which they renew the defence.

Attack. If the ravelin is only retrenched by a tambour at the gorge, the assault may be given at all three breaches simultaneously. As soon as the storming party have cleared the top of the breach, sappers are brought forward to make a lodgement on it with gabions, which has been fancifully called the magpie's nest. Howitzers are then brought into this lodgement to answer the fire of the retrenchment; upon which likewise a heavy fire of shells is directed from the batteries on the crest of the glacis. The interior of the bastion is crossed by the sap in the usual manner; the counterscarp of the retrenchment is crowned with batteries by which the parapet is to be destroyed; and, this being effected, the assault is given.

Such are the usual operations in the attack of an ordinary fortress; and such likewise is the defence when a proper resistance is made. The hope of protracting the latter beyond this period must depend almost entirely upon the feeling and spirit of the inhabitants. The siege of Saragossa† in the Peninsular War presented a memorable example of a defence continued, from street

* A hint for raising these works was taken from the practice to which the Turks, at the siege of Candia, were obliged to resort to gain a plunging fire into the bastion of S. André, the fire of which they, until then, had been unable to get under.

* On the night of the 6th of April, 1812.

† *Rel. des Siéges de Saragosse et de Tortose*, by General Baron Rogniat, Paris, 1814.

to street, for twenty-three days after the whole of the works of the place had been penetrated. But such instances of patriotism are so rare, that they are rather to be admired than anticipated. The siege which we have been supposing, would occupy upon a fair calculation nineteen or twenty days, from the first day of breaking ground.

Protraction of the defence by salient outworks.

When a place is fortified with very salient outworks, it becomes convenient to direct the central line of approach on the capital of a bastion, and the others on those of the two collateral ravelins, for the reasons which have been formerly given. The process of the attack will, however, be the same as that above described, so far as the completion of the third parallel: but the sapping must afterwards be conducted only up the glacis of each ravelin where, at the salient angle of its crest, counter-batteries are formed as before; the approaches on the glacis of the intermediate bastion being suspended on account of the reverse fires from the ravelin on each side. Before the construction of the breaching batteries on the glacis of the ravelin, it may be necessary to execute a portion of a fourth parallel in the direction of a line joining the extremity of the counter-battery on each ravelin, and extending about midway from thence to the salients of the bastion: in order to afford cover for bodies of troops, who may keep down the fire from the works, and protect the sappers in forming the breaching batteries which are to act against the ravelins. These latter works being breached, may be assaulted, and a lodgement may be formed about half way up each of the breaches, where it will not be exposed to the fire of the redoubt in the ravelin. A trench is next driven by full sap from the lodgement to the counterscarp of the redoubt; and, turning to the right and left, the sappers extend this trench to about the middle of the face of each ravelin. In this excavation, if space permits, artillery may be placed to breach the redoubt: but should the narrowness of the ravelin prevent the formation of such a battery, either a portion of the mass of the ravelin must be destroyed by a mine, and the redoubt breached, through the opening thus made, by a battery purposely constructed on the glacis; or a miner may be attached to the escarp of the redoubt, where, under cover of timbers placed on end and leaning against the wall, he may make an entrance and place powder in chambers formed under the capital of the work. This being fired, a breach will be made in the redoubt, by which an assault may be given. Should it succeed, the interior of the work will be occupied by a lodgement of the besiegers; from which a fire of artillery may be directed both against the opposite curtain, and against those flanks of the collateral bastions which have a view of the intended descent into the main ditch. Since this redoubt commands the ravelin in which it is placed, the defenders will be obliged to abandon any retrenchments which they may have made in the latter; and, subsequently, the redoubts in the re-entering places of arms, which are also commanded by the ravelins. The outworks being now in possession of the besiegers, and there being consequently no reverse fires to annoy them, the approaches on the intermediate bastion may be commenced by sapping up its glacis, and crowning it with breaching and counter-batteries as before; but under the protection of the troops in the fourth parallel, which is completed for the purpose by driving a portion from the extremities of the counter-batteries to join the part already executed. A place thus fortified may reasonably be expected to hold out seven days longer than one constructed on Vauban's First System.

CHAPTER IV.

Subterranean Attack and Defence.

Management and effects of a system of countermines.

In the preceding detail of the ordinary processes of a siege, we have purposely omitted all reference to the use of mines either by the assailants or the garrison: because, as such works cannot in every case be employed; and as they form rather occasional aids than component and indispensable parts of the hostile operations; it has seemed useless to interrupt the general narrative of the attack and defence above ground, and to distract the attention of the reader, by intermingling with the main subject any unconnected notices of subterranean warfare. Moreover, this method of assailment constitutes so distinct a branch of the Art of Sieges, as well to deserve a separate consideration; and the present appearing the most appropriate place wherein to introduce also some explanation relative to the management and effects of the system of defensive mines, of which we have, in a former Part, already described the nature and construction; we shall devote the Chapter before us exclusively to a brief sketch of the subterranean operations, to which both the assailants and defenders of a fortress may have recourse in order to accelerate or retard its capture. And here it may at the outset be observed, that the success of either party will greatly depend upon the latitude given by the other to his efforts, either through impotence of means, or want of equal address and intelligence.

Defence.

If a fortress has been beforehand provided with such a regular system of countermines as we have already described, the advantage of preparation for a subterraneous conflict should, with proper energy, lie wholly on the side of the besieged. As soon as his enemy, by breaking ground, has indicated the front of attack, he should drive forward branches to meet him from the ends of the listening galleries even so far as the points at which the demi-parallels are made, with a view of commencing the work of destruction as far off from the place as possible. It is likewise recommended to sink shafts at the ends of the listening galleries, from the bottoms of which other galleries may be driven towards one another so as to form by their junction a second envelope, which may intersect the line of the besieger's approaches in whatever way it may be directed. For then, on hearing him at work, either from this new envelope, or from the ends of the above-mentioned branches which have been driven forward, he may soon be reached, and smothered by a small charge sufficient to blow in the wall of the gallery behind him, yet not great enough to produce a crater. For it is obviously disadvantageous to the besieged that his mines should produce any craters if he can possibly manage otherwise; since they become so many places of cover where the enemy can immediately make lodgements. But if a crater is inevitable, it should be made of the largest possible size, as, by reason of its shallowness in proportion to its width, it can be more readily seen into from the place, and consequently will afford less cover. The besieged having his work all ready need do no more than listen attentively; hearing without being heard; announcing himself only by effects

as prompt as destructive; and rendering it as difficult to escape from, as to reach him.

Attack.

Let it now be supposed that the besieger has begun by sinking shafts behind the parapet of his parallel, at forty yards from the ends of the branches of the besieged; and that, in order to avoid destroying his own works upon the surface, he intends advancing twenty-six or twenty-seven yards before he charges his globe of compression. Then since miners, as already explained, can be heard at work as far off as thirty yards, it is evident that the besieger, as soon as he shall have driven about ten yards of gallery, must excavate the remaining sixteen or seventeen in the hearing of his enemy. From the moment the latter has heard him, he drives forward without loss of time, in a parallel direction, a branch sixteen or seventeen yards long, which will of course extend beyond that of the besieger by two or three yards: so that the latter may be immediately taken in reverse, and smothered by a charge calculated to destroy a good portion of his gallery. Here it may be seen that the besieged can, if he takes care, be always beforehand with the besieger, the nature of whose work is calculated to occupy much more time than that of his enemy; for he has to excavate a large chamber, lodge a great quantity of powder, (transported thither by night for greater security from accident,) and tamp a great length of branch. Now the best thing which the besieger can do, in this case, from the moment that he may have reason to apprehend that the besieged has got into his rear, is to stop short immediately and charge his globe of compression: the springing of which, although perhaps rather premature, may nevertheless crush the besieged in his new works, as well as blow in his galleries of earlier construction. The miner of the besieger, however, may avoid by a timely retreat the destruction preparing for him: as he can easily distinguish that his enemy is tamping and not driving, by the difference of sound, which in the former case recedes, and in the latter draws nearer.

The disadvantages which may result to the besieger from thus prematurely springing his first globes of compression are as follows: 1st, The too great proximity of his own trenches on the surface may entail their destruction. 2dly, By his not being perhaps sufficiently near the ends of the branches of the besieged, neither the latter nor the envelope will be much damaged. 3dly, He will not have made the desired degree of progress. Immediately after the springing of the first globes of compression, the besieged will go to the ends of those parts of the branches which may have escaped destruction, and drive forward in order to lodge charges under the borders of the craters. This will easily be done, as the springing of the globe of compression will have produced no bad smell in the broken galleries; and he will have the start of the besieger, who has to make a lodgement on the borders of the crater before he can even commence sinking his shaft. This lodgement may therefore be repeatedly destroyed by the besieged, if the sinking of the shaft be made on the border of the crater; and the shaft may as often be choked up by the earth being blown into it, if it should be sunk from the bottom of the funnel The besieger will have to surmount this difficulty after the springing of each of his series of globes, in advancing towards the place. Hence it may be conceived what labour, danger, and loss a well-countermined glacis must occasion to the besiegers; and the advantage in favour of the besieged is probably not overrated in a computation that the delays resulting from all the chicaneries of a well-managed subterraneous defence are capable of adding two months to the duration of a siege. Such is the estimate of Bousmard, who supports his opinion by citing the example of the siege of Schweidnitz by the Prussians in 1762; and to this may here be added the more memorable siege of Saragossa, in the last Peninsular War, the long defence of which, even after the fall of the fortifications themselves, was chiefly owing to the multitude of mines sprung in the very streets.

System of fougasses.

Besides the regular systems of mines described in the foregoing pages, there is a more expeditious method of employing the same kind of means in the defence, although upon a diminutive scale. And this is by a system of fougasses, which can be made even when the time is too short to allow of establishing galleries. It consists in burying under the parts of the surface which are most likely to be attacked, well calked and tarred boxes or even barrels full of powder; and laying in a trench, which is afterwards filled up, the troughs destined to convey the fire to the charges, either all at once or successively. The troughs extend even to within the works, in order to facilitate the springing of these expeditiously constructed mines; to ensure the success of which, the following precautions ought to be taken. See fig. 21, plate v.

1st, If the hole in which the powder is to be lodged is at all damp, it will be well to make it still deeper, and then fill up the bottom to the required height with loose stones. This will enable the water, if there be any, to filter down to the bottom. 2dly, The troughs must be laid at a depth of six feet, at least, underneath the surface, to prevent their being disarranged by the fall of shells; and if more than one trough is to be laid in the same trench, they must be separated by at least a foot of well-trodden earth, so that the first which may be fired may not shake or disarrange the other. 3dly, Care must be taken in refilling the shafts* and trenches to plough up the whole of the surface equally, so that nothing shall indicate to the enemy the situation of the trenches and charges. 4thly, The ends of the troughs and hose must reach to such places within the works as shall secure them from sudden attacks, and enable them to be sprung with the utmost coolness at the most favourable moments. It will not suffice for the security of these mines that their troughs terminate behind the banquette of the covert-way: they must be carried through the counterscarp to be fired at the bottom of the ditch. Otherwise the enemy, by assaulting the covert-way, might discover and tear up all these troughs, and utterly prevent their being employed against him, when he establishes his lodgement on the crest of the glacis. The boxes should be placed so as to destroy the double saps along the capital, the trench-cavaliers, the crowning or lodgement on the crest of the glacis, and the breaching batteries. They may likewise advantageously be sunken in dry ditches, both of the outworks and body of the place, at spots at which it is most likely that breaches may be made. Their troughs must be conducted to the gorges of the outworks or behind the tenaille, or wherever they may be fired with security. Those likewise which may be employed for the defence of the breach, or are placed in the terrepleins of the works, must have the ends of their troughs within the redoubts or retrenchments. Each trough must be marked

* In the present case these are usually called wells.

with the number that distinguishes the box to which it communicates; and the exact place of the latter is correctly laid down on a plan of the works, so that the springing may be regulated as occasion shall dictate.

Fougasses are likewise an excellent means of demolishing any flêche, redoubt, retrenchment, traverse, or any other temporary work which having, until its capture, been of service to the defenders, has then ceased to be so, and may even be of advantage to the enemy into whose hands it has fallen. The facility and economy of a system of fougasses, and the similarity of effects produced by them with those of regular mines, might, at first sight, induce a preference to be given to them. But it must be remembered that though such means may be successful against an enemy unable to employ mines himself, they are altogether insufficient and even null against a besieger who has it in his power to do so. For ceasing to advance upon the surface, beyond the influence of the fougasses, he may drive galleries as far as he pleases; and not only blow in the counterscarp but at the same time tear up the troughs without giving an opportunity of disputing one inch of ground by their means. It must not, however, be concluded from this that the employment of these boxes of powder should be proscribed in the defence of places: they may, on the contrary, often be appropriately used, conjointly with regular mines. And if judiciously managed, this mixture may lead the besieger into a serious error, by making him mistake their explosion for that of the regular mines, and either induce him to take precautions entailing useless labour, loss of time and powder, or lull him into a security which may afford the defenders opportunities to put in execution more powerful means of destruction. Fortification.

PART V.

FIELD FORTIFICATION.

CHAPTER I.

General Principles of this Branch of the Art.

Under the term of Field Fortification, in contradistinction from the Art of constructing, defending, and assailing Permanent Fortresses, is usually comprehended the whole business of disposing and preparing such temporary works, and improving such natural advantages of the ground, as may assist and support the operations of an army in the field, and enable it partially to impede, or totally to prevent, the advance of an enemy, though in superior force. In Field Fortification, therefore, every expedient is good, which effectually conduces to arrest or retard the progress of an adversary. In this, perhaps, more than in any other branch of the profession, is the engineer enabled to display his intelligence: here few restrictions shackle his inventive genius; the opportunities of displaying it are frequent; and the materials are commonly abundant. Not so in Permanent Fortification: where the rarity of the occasions which present themselves for the formation of new works discourages that devotion to the subject which is necessary to the attainment of excellence; and where the vast expense of the constructions operates as a serious check to the adoption of even the most meritorious suggestions.

It would be an endless undertaking to enumerate the multitude of objects, which may be classed under this division of the Military Art. With regard to works thrown up in a plain open country, certain principles and certain rules deduced from experience may be laid down; but for the greater part the intelligence of the individual must be his sole guide in the judicious application and use of the means and materials which circumstances may place at his disposal. Barren, indeed, must be that country which offers none to second a discerning officer in the task allotted him. A farm-house, a mill, or a Church surrounded by walls, may with very little expense be converted into an excellent military post, by loop-holing the walls, barricading the entrances, or erecting traverses or portions of parapets in those places which offer a good flanking fire; or, in a word, by turning to account every means of resistance which may present itself.

With regard to those Field-works for which, as we have said, certain rules may be observed, it will be sufficient briefly to show that, although in magnitude and importance they are inferior to the works which constitute permanent fortifications, nevertheless the general rules which govern the construction of the latter are in a great measure applicable to the former. In the first place, the immediate object of both is equally to procure cover from the assailant's fire, and to place between him and the defender an obstacle which he must overcome. These ends are obtained by excavating a ditch, and throwing up the earth to form a parapet or covering mass. The impossibility of carrying about with an army any implements of construction beyond the mere pickaxe and spade, naturally imposes limits to the magnitude of the works; and therefore the maximum of height that it is found possible with these simple means to give to the crest of the covering mass is twelve feet. And the same dimensions, twelve feet, must be considered the maximum for the depth of the ditch; this being the greatest depth from which a man can throw up the earth to those who are employed above in giving to the mass its requisite shape.

The reader will find represented in fig. 1, plate v. a portion of the parapet and ditch of a Field-work of the most common profile: that is with a mere command of seven feet and a half; and we proceed to give the nomenclature of its various parts, together with their uses, in order that the contents of the following pages may the more readily be comprehended. A B is the height of the parapet: a dimension which will depend upon the nature of the surrounding country; as it is necessary that the interior of the work should be entirely covered from the view of the enemy. B C is the thickness of the parapet; and this must be regulated according to the nature of the attack to which the work may be liable: for instance, if only exposed, by its situation, to an infantry attack, three feet will suffice; if the enemy Plate v. fig. 1.

Fortification.

can bring artillery against it, but have only six-pounders in his Field train, the thickness of the parapets may be safely restricted to six feet; if nine-pounders to nine feet; and if twelve-pounders to twelve feet. For experiments have shown that at a short range a musket-ball will penetrate into well-beaten ordinary soil about eleven inches; a six-pound shot, four feet; a nine-pound shot, six feet; and a twelve-pound shot, ten feet. We have not here reckoned upon a greater caliber than twelve-pounders, because eighteen-pounders and twenty-four-pounders are never used in the Field; although the former have very lately been considered a part of our Field train. The height of the ordinary race of men being considered as constant, the distance of the banquette *a b* below the crest A is made equal to four feet or four feet and a half, to enable the troops to fire conveniently over the parapet. The base of the slope of the banquette is generally made equal to twice its height *a c*; and its breadth (*a b*) is usually three feet. A level space H L, of about eighteen inches in breadth, called a berm, is left between the foot of the exterior slope of the parapet and the escarp of the ditch, for the purposes mentioned below.

The superior slope A I of the parapet is directed so that the enemy may be discovered from head to foot when upon the edge E of the counterscarp: this slope must be considered as an evil in one respect, for it is evident that, if the upper surface were horizontal, the parapet would be much stronger. To preserve therefore to the crest A an adequate strength, the maximum depression of this slope is fixed at one-sixth of its breadth; and this limits in some measure the height of the parapet. The interior slope A *b* is also an unvarying quantity: its horizontal breadth is made equal to one foot and a half to give it a strictly sufficient solidity, and at the same time to enable the troops to approach the parapet conveniently when firing. The exterior slope I H varies with the nature of the soil; but in ordinary cases it forms an angle of about 45° with the horizon. I is called the exterior crest of the parapet; A the inner crest or covering line. The berm H L ought not to be made wider than one foot and a half, lest it should offer too great a facility to the escalade; it might therefore appear advisable to dispense with it altogether, but it is too useful in the construction of the parapet to allow of being suppressed. Moreover it prevents the rolling down of the earth; removes to a greater distance the pressure of the covering mass; and thereby contributes to the solidity of the work. This berm, usually constructed upon the natural level of the soil, ought, in every case, to be at least six feet lower than the interior crest to prevent the enemy from seeing into the work when he may have reached the berm. The slopes both of the escarp L N and counterscarp M O must vary with the soil, with the means employed to support them, and with the intended duration of the work. The breadth and depth of the ditch will vary according to the thickness and height of the covering mass. When a covering mass is thrown up without either banquette or superior slope, it is called an *epaulement.*

The reader being thus acquainted with the nature of covering usually obtained in Field-works, we may proceed, first, to describe the plan or outline of such works; next, to touch upon the details of construction; and, ultimately, to point out the means whereby defences of a temporary nature may be strengthened or rendered more difficult of capture.

CHAPTER II.

Single Field-works.

The redan. See fig. 2.

Of all the works which an engineer may be called upon to construct during a campaign, the most inconsiderable is the *redan.* This work is open in rear; and is therefore only employed to form part of a line of works destined to cover a camp, to defend the avenues to a village, dike, bridge, or defile, &c. Its principal defects, considered as a single work, are that its ditch is without defence; and this defect it has in common with most works of a mere temporary nature. Besides, as it is invariably found that soldiers when placed behind a parapet will fire directly before them, that is, at right angles to the parapet, it follows that there is a large undefended sector in front of every redan. This may in a measure be remedied by cutting off the salient angle with what the French call a *pan coupé:* that is, a portion of the parapet having its crest perpendicular to the capital of the work. There is no stated rule for fixing the length of face of a redan: though that which is usually given to it is fifty yards. The redan when thrown out in front of other works to increase their strength receives the name of *flèche.*

The lunette. See fig. 3.

The *lunette* or *bastion* is a work rather more considerable than the redan, being composed of two faces and two flanks. Its object is to enclose more advantageously the interior space, and permit a more direct fire upon the sides. The lunette being, as well as the redan, open in rear, is employed only in cases similar to those for which a redan would be constructed. This work is of very common use, owing to its simplicity, facility of execution, and easy adaptation to any ground. There is nothing arbitrary in its form and dimensions, which must be determined by local circumstances: but in ordinary cases and on level ground, its faces may be fixed at sixty yards long, and its flanks at ten. The defects of the lunette are the same as those of the redan.

Bonnet de prêtre. See fig. 4.

The French engineers give the name of *bonnet de prêtre* to two redans so connected as to afford a mutual defence. It therefore consists of two faces A B, C D, and of two flanks A E, E C, usually shorter than the faces. This work being likewise unclosed in rear, its application must be subjected to the same restrictions as in the case of the two former: it is generally employed to cover a bridge, and its faces are then defended by batteries placed on the opposite banks of the river. The bonnet de prêtre is a more efficient work than the lunette, as its salients are better defended; it has no dead sector in front, but the ditches of the faces are unflanked. The construction of this work may be regulated as follows. Make the line of the gorge B D equal to one hundred yards, and the capital I K equal to fifty; at right angles with I K set off I A, I C each equal to twenty yards; set off I E also equal to twenty yards; join the flanks A E, C E, and faces A B, C D. The angles A and C will by this construction be equal to 72° 30′, and therefore will exceed the minimum prescribed for such angles: it being a rule in fortification, both permanent and temporary, that salient, that is, projecting angles, shall never be made of a smaller opening than 60°. The angle A E C will be a right angle whereby the best possible defence is afforded to the salients A and C: it being likewise a rule in fortification that a line which flanks another shall make with it, at least, an angle of 90°; and this is in consequence of the incorrigible habit which is found in soldiers of

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firing perpendicularly to their parapet, in spite of all the care which can be taken to make them direct their fire upon any particular point.

The redoubt. See fig.

The redoubt is an enclosed work without flanks, and is usually made of a quadrilateral form. On a flat even country the redoubt is generally made square; there being no reason why one face should be made longer than another, or one angle greater than another. But on a varied surface, it is necessary to adapt the shape to the nature of the country. An opening is left in the middle of one of the sides for communicating with the exterior; and a traverse is thrown up within, to prevent the enemy from seeing into it. The quadrilateral redoubt is defective; inasmuch as the dead sectors in front of its angles favour the enemy's attacks upon four different points, and weaken the defence by dividing the resistance of the garrison. Endeavours have been made to correct this defect by giving to the redoubt a circular form; but this is only substituting one evil in lieu of another. A circular redoubt would with equal developement of parapet circumscribe a greater space, and in this point of view is advantageous: but its application to the ground is difficult; its figure makes the resistance on all sides equal; and the distribution of its fires prevents any particular side (which may be most liable to attack) from receiving an adequate proportion of defence, at the same time that it affords a greater fire than necessary upon other points of difficult access. The angular redoubt, on the contrary, may have its principal faces directed against the points most important to be defended; it is besides, more easily executed and applied to uneven surfaces. The deadness of the angles may in a measure be remedied by the expedient suggested for the redan, that is, by making a pan coupé of six or eight yards in length. The size of a redoubt is always proportioned to the garrison which it is destined to contain. For lining the parapets, the calculation is that each soldier occupies three feet of front. The interior free habitable space is regulated by the consideration, that a square fathom should be allowed for every four men. By interior free space is understood that comprised within the foot of the slopes of the banquettes. In the largest sized redoubts the free habitable space will always be sufficient for the convenience of the garrisons usually thrown into them; and the smaller ones, being seldom occupied, excepting in moments of actual resistance, it is of little importance—provided they have sufficient men for the effective lining of their parapets—whether the habitable space, as it is called, be equal to that above prescribed. Nevertheless, all French authors have thought it necessary to lay great stress upon the mathematical accuracy with which the capacity of the work is adapted to the number of men who are to occupy it; and each has laid down some rule which he thinks preferable on this account to that of his predecessor. From the nature of the outline of a redoubt, it is almost needless to acquaint the reader that its ditches are without defence, or in other words, dead. The manner of palliating this evil will be shown in another part of this Essay.

Star forts.

The next enclosed work in order of importance is the star fort. This is constructed either upon a triangle or upon a square: in the first case it has six points, and in the latter eight. The hexagonal, or six pointed star fort, is constructed upon an equilateral triangle A B C of ninety yards length of side; by dividing each side into three equal parts, and describing on the centre one an equilateral triangle D E F. By this arrangement the salient E is defended by the fire of the lines A D and B F; and the points A, B receive a similar defence from the faces D E and E F: so that the defect of dead sectors is much diminished, if not totally removed. This star fort is a little defective in its flanking: for the re-entering angles being obtuse, the fire from F is not directed precisely upon E, and we have already stated how difficult it is to induce troops to fire obliquely. The entrance $m\ n$ is made in a re-entering part, being there less exposed to attack, as it is further removed from the enemy and protected by a cross fire.

See fig. 6.

See fig. 7.

The star fort with eight points is constructed upon a square, the sides of which may be ninety yards long. Each of the sides is divided into three equal parts; and upon the central one is described an equilateral triangle. In this, as in the last-mentioned work, the salients are but obliquely flanked: but this defect is not so sensibly felt as to render it necessary to resort to constructions foreign to the simplicity indispensable in Field-works, which it is almost always required to trace out expeditiously, and often with the aid of no other instrument than a correct eye. Most of those minute perfections, to which so much consequence is attached by mere theorists, and which are perceptible only on paper, would not prolong the defence of a work one single minute. It can scarcely be too often repeated that it is necessary in Field Fortification to avoid that spirit of minutiæ, which is too apt to lose sight of greater objects in running into details of little or no importance. Four of the points of this octagonal fort are less acute, and therefore more solid than those of the former work: but a more real advantage, and one which ought to obtain for it a decided preference over the latter, is that with equal length of parapet its interior space is greater.

Bastion forts, or Field forts. See fig. 8.

The bastion fort considered as a Field-work should be constructed only upon the square or pentagon. The distance between the points of the bastions, or in other words, the exterior side A B of the polygon, may vary in length between one hundred and two hundred yards, which allows of great latitude and facility for the application of this kind of work to almost every site. The reason why A B cannot be made shorter than the minimum above prescribed, is, that owing to the relief of the works, the ditches near the centre of the curtain would not be discoverable from the parapets, and would consequently be dead: besides, the flanks would dwindle into insignificance. The range of common muskets also requires that the extent A B of the front should not exceed the above maximum; for it is an axiom that "lines, which have to defend a salient point, must not be further removed from it than will enable the musketry to range beyond that point, and to take effect upon the enemy before he reaches it."

Star and bastion forts, and particularly the latter, are employed in fortifying important posts. Their construction ought to be of a solidity approaching to that of mixed fortifications; which, though not revetted with masonry like permanent works, are nevertheless intended to last several campaigns. These forts will not only serve as posts of importance, but are also useful as depôts for stores of every description, for which their spaciousness renders them fully eligible. They should therefore be so well conditioned as to apprehend nothing from sudden assaults, but should compel the enemy to break ground before them. A Field-work which is honoured with a formal attack, or which compels the enemy to resort to more than ordinary means for its

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CHAPTER III.

Continued Lines.

Lines. Several works placed in succession parallel to, or surrounding, a position, generally receive the name of lines. There are two kinds of lines; continued lines and lines with intervals. Continued lines consist of an uninterrupted range of parapet. Lines with intervals are formed of isolated works—whether open at the gorge or enclosed —placed at convenient distances from each other, and affording a mutual flanking defence. Continued lines are mostly employed where a pass is to be closed. And lines with intervals where it is intended to oppose resistance to a vigorous attack: because the detached works which compose them may be more carefully constructed and better defended; serving as strong points round which the troops may manœuvre; and thus combining, whilst on the defensive, all those moral advantages of the offensive which result from the feeling of superiority. Hence continued lines are best adapted to frontier defences, and lines with intervals to camps and fields of battle: nevertheless, the preference ought always to be given to that, which can be soonest prepared, and defended with fewest troops.

Continued Lines: with redans; The different modes of constructing continued lines are as follows: with redans, tenailles, cremaillères, or bastions. Vauban, in his *lines with redans*, placed the latter at distances of two hundred and forty yards from centre to centre. This is at present considered too great a distance; and it has been proposed to place them at one hundred and eighty yards, by which the faces of the redans will mutually derive a nearer defence. This is, however, at best, but a weak line; and the frequency of its employment in war can only have proceeded from the readiness with which it can be constructed. Another way of improving upon Vauban's outline is by breaking the curtain B D into a very obtuse redan B C D. With this alteration the works assume the name of *queue d'hironde*, or *swallow-tail lines*. This construction, although better than that with redans, is nevertheless far from being good: for, although the parts of the line between the redans are defended by the fires from the faces of the latter, yet upon an equal developement of parapet the queue d'hironde line presents three salient points, whereas the redan line has only two; and as the points project equally towards the front, they are all liable to be attacked at the same time. The curtains, also, of Vauban's line, are less exposed to the ricochet fire, than the branches of the swallow-tailed construction. The salients are the principal points of attack, because they are closer to the enemy; and because they have sectorial spaces in front of them undefended by direct fires: while they are also easily enveloped by the enemy's converging fire. A means of correcting the defect arising from too many points of equal saliency, would be to carry forward the salient of the great redan B C D, making its faces perpendicular to those of the small ones: so that upon a line of one hundred and eighty yards only two points of attack would be offered; and the salients would moreover be well defended by flanking fires.

See fig. ' See fig. 10. See fig. 11.

with tenailles; The *tenaille line* is composed of redans of equal dimensions. Their capitals are usually seventy yards long, and their demigorges one hundred. There exists so great a similarity between this and the former outlines, that to specify the minute differences in their defensive properties, which writers on fortification have remarked and dwelt upon, would be to consume time to no purpose; and these lines are here described merely to complete the usual enumeration. One great fault common to them all, is, that their long branches are exposed to the enemy's enfilade fire; and in an open country this evil will be more sensibly felt in the tenaille line than in any other. See fig. 12.

with cremailleres. Lines *en cremaillère* are composed of a succession of faces and flanks perpendicular to one another. The faces may be made one hundred yards long, and the flanks twenty-five, still supposing them constructed upon a flat and open country: for, on an irregular surface, all the branches may vary considerably in length from the general dimensions; the most essential rule being that the works should conform to the shape of the ground, and have their salient points on eminences. The cremaillère line is superior to any other, for the purpose of uniting principal works placed at too great a distance for mutual defence. In this case the cremaillères ought to change their direction at the centre *a* of the line, whence there will result a good cross fire before the middle of the interval. See fig. 13.

The bastion line. If particular circumstances should make it requisite to give to a line a more than ordinary degree of strength, there is no doubt but the bastion outline ought to be preferred. Its principal advantage is that every part of the ditch is well seen into and flanked: but the salients have not all the defence which could be desired. There are certainly cross fires in front of them, but these scarcely range beyond the counterscarp and leave great open spaces X without any at all. This may, in a measure, be remedied by breaking the curtain, for then the fire of the half curtains directed upon those spaces X will render the access to the salients more difficult. The bastion line is more troublesome to construct than any other, owing to the quantity of earth which requires removing between the flanks and the curtain, when the counterscarp is directed, as in permanent fortification, to the shoulders of the bastions; and this may account for its not being oftener employed. It is evident that, if the counterscarp were traced, as in other works, in directions parallel to the faces, flanks, and curtain, the ditches of the faces would be unseen from the opposite flanks, the sight being obstructed by the mass of earth in front of the curtain. When there is not sufficient time for removing the entire mass—and it seldom happens that there is—the evil may be palliated by sloping away the earth in the direction of the line of fire drawn from the crest of the parapet of the flank to the foot of the ditch of the opposite face: whereby the ditch of the face will be perfectly laid open to the fire of the opposite flank. Some writers object to this remedy, as facilitating the descent of the enemy into the ditch: but it may be observed that the descent into the ditches of Field-works is in practice usually an easy matter; and those ditches should be regarded rather as excavations which have served to furnish earth for the covering masses, than in the light

See fig. 14. See fig. 15. See fig. 16.

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of serious obstacles to the enemy's attacks. Besides, even though the facility of descent should be admitted to be of great advantage to the assailant, it is evident that in availing himself of the slopes here mentioned, he must expose himself to a reverse fire from the flank behind him, and this is not likely to augment his assurance.

The redan bastion line.

The line just described is applicable to any surface: but that which may next be mentioned having its various parts given in numbers, is unfit for irregular surfaces. It certainly appears, however, the best that can be used on an even country, where only a limited length of retrenchment is required; and though thus restricted in its application, some notice of it in this place is due to the inventor, Colonel Dufour, (Director of the Military Academy of Grave,) to whose excellent Work on Field Engineering the compilers of the present Article are bound to express their obligations. At each end of a side A B four hundred yards long, erect perpendiculars A P, B Q. Set off on the latter A D, B E, each equal to fifty yards, and D P, E Q each equal to thirty yards; join D and E; on D E take D G, E H, each equal to sixty yards, and bisect D E in C. Draw A G, B H, and produce those lines indefinitely; join C and P, C and Q, and make C M and C N each equal to A G or B H. Then, in order to obtain flanks sufficiently near the salients A, C, and B, to afford those points an adequate defence, let fall from G, M, N and H, perpendiculars G g, M *m*, &c. upon the lines of defence M P, A G, &c., and join the interior extremities *m*, *g*, &c. of the flanks, to form the curtains. This outline is superior in many respects to any of the former; but it is certainly rather too complicated, and is moreover inapplicable to every kind of surface: it can, therefore, be entitled to a preference over the common bastion line only in the circumstances already mentioned; and when these occur, its advantages are as follows. Suppose two fronts of fortification on the lines A C, and B C traced upon the usual principles, it will be found that the redan-bastions in fig. 17 are more spacious than the ordinary ones, and that the flank M *m* is longer in the former than its corresponding flank in the latter would be, which is strictly conformable to the principles of the Art as it has to defend the point of attack. G *g* indeed will be smaller, but this is attended with no inconvenience, since its fire is directed upon a point not much exposed. It may, however, be noticed as some defect, that the fire of the short flank G *g* when prolonged in a direct line would fall within the salient of the advanced bastion at B, and expose its defenders to the risk of injury from their own comrades.

See fig. 17.

CHAPTER IV.

Lines with Intervals; Têtes-de-pont, &c.

Lines with intervals.

Lines with intervals are composed of isolated works, such as redoubts or redans placed at certain distances asunder. In determining the situation of these works, it must be observed that the intervals between them should never be greater than two hundred yards; so that they may be able to defend one another by a crossing fire, at an efficient range. The outline of each work must also be so disposed that the faces which are to produce that crossing fire between two works, shall make with each other an angle not less than, nor much exceeding, a right angle. The military world has long been divided in opinion whether the preference should be given to continued lines, or to those with intervals. The former seem to have been held in highest estimation until after the commencement of the XVIIIth Century; for the greatest number of retrenchments made by the French and by their opponents during the reign of Louis XIV., and particularly during the Wars of the Succession, were continued lines. In our days this manner of retrenching armies is rejected; and when the nature of the country will admit of it, that of isolated works has the preference. Lines with intervals have over the other species of lines the following advantages. 1st. They are more easily applied to the ground, and made to occupy the points most essential for the defence; not being shackled by the conditions which must be observed in outlines where all the parts are connected together. 2dly, They require less labour, and consequently enable the engineer to give a greater degree of perfection to the works within a determined time, and with fewer workmen. 3dly, They require fewer troops for their defence, having a less developement, and thus allowing a greater force to be directed upon the most exposed points, or a greater number to be kept in reserve. 4thly, By this disposition the troops may with facility pass from the defensive to the offensive, and *vice versâ*, as may best suit the occasion: whereas, when lining a continuity of parapet, the same troops possess no advantages except such as may be derived from a judicious adaptation of the outline; and having no facility of issuing from behind their cover, are restricted to mere defensive operations, which are apt to produce an unfavourable effect upon the courage of the soldier. It may be remarked, in conclusion, that continued lines ought to be employed only in situations of moderate extent, where a small number of men being sufficient for their defence, a considerable portion of the army may be kept in reserve at points favourable for offensive movements.

Choice of positions.

In the choice of positions or situations for the encampment of an army, it is evident that elevated ground should always be preferred, when its extent is not disproportionate to the number of troops: in order to increase the difficulties of the attack, and permit the defenders to see the works and dispositions of the enemy while their own are wholly or partly concealed. A superiority of command, also, renders it possible to take advantage of any movement of the enemy by falling rapidly on his convoys or attacking his columns on their march. Positions are, however, often unavoidably taken up in a plain country; and it may be observed that no great inconvenience ensues from the occupation of such situations, provided they are protected by natural obstacles, or by works expressly constructed, and that by any means the enemy is prevented from approaching near enough to annoy the lines by his fire. But if the position should be commanded within range of artillery, the most disastrous consequences may be induced: for the troops being either exposed to heavy loss, or driven from their posts to obtain shelter behind woods or other cover against the enemy's fire, the works may be assaulted and carried before the defenders can be rallied from their confusion.

Whether in plains or on eminences, the approaches towards the ground occupied by the enemy should be well guarded by a chain of outposts, which must sur-

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round the encampment within view of it and at the distance of about a mile from it in every direction: so that, on an alarm being given, there may be time for the troops in the lines to put themselves in a posture of defence. These outposts should be covered by woods, villages, or houses; or if no such cover exists, redans, as before described, must be constructed for their protection. Within the chain of outposts, and at two or three hundred paces from the encampment, redoubts or batteries must be formed: for the purpose of protecting the line by their crossing fires, and principally to secure the wings against any attempt of the enemy to turn them, or to get to the rear of the army, by which the supplies from its magazines, and its own retreat, should this become necessary, might be entirely cut off. The disposition of these works, next to the choice of the position, demands the serious attention of the engineer: since on it depends, in a great measure, the success of the army in maintaining its ground; and, consequently, the probability that the enemy may be compelled to retreat and leave the field free for the prosecution of offensive operations. When, therefore, the position is on an eminence affording a good view of the neighbouring country, and particularly of the avenues by which an enemy might approach, the redoubts should be constructed at intervals on the salient points in front of the line, where they may defend those avenues by direct and flanking fires from an artillery sufficiently numerous to prevent the enemy's columns from advancing without experiencing a serious loss. As the enemy may attack and attempt to storm some of these redoubts, they should evidently defend each other reciprocally, and be capable of making a powerful resistance in front. For this latter purpose they should be placed on the crests of the heights which they occupy: that they may be able to graze with musketry the descending ground about them; and if, from the steepness of the slope in any part, this should be impossible, collateral works should be constructed in situations where they may see and defend that part by which an enemy would otherwise advance unmolested against the principal work.

In general, the highest point in the line is the key of the position; and, as the retention of this is an object of the utmost importance, it should be occupied by a redoubt of the strongest kind. This point being a pivot about which the whole army manœuvres, it is plain that it should be situated about the centre of the line; but as, in some cases, it may happen to be in one of the wings, then additional precautions will be necessary to prevent it from being cut off from the other parts of the line: such as making good communications to it, by which succours may be sent in force when it is hard pressed by the enemy. Such communications should also be made when the divisions of an army are separated from each other by woods, marshes, or streams: passages should be cut through the first, and causeways or bridges formed over the others; in order that in every part of the encampment troops may be able (if possible out of the enemy's sight) to march to each other's support. Natural obstacles greatly increase the defensive properties of a position; and if there should be a river at the foot of any part of the eminence on which the army is situated, and near enough to be subject to the fire of the artillery, it would be impassable by the enemy and would completely protect that part of the line. It may be here observed that an army encamped possesses many advantages over the garrison of a fortress: for the degree of resistance that can be opposed by the latter is always known to the enemy, and the permanent nature of the works prevents the plan of operations from being changed; so that the enemy can regulate his dispositions accordingly. The case is different with an army in the field, which can vary its measures with the nature of the anticipated attack: either by opposing force to force, or by surprising the enemy; or by taking advantage of the localities to prevent his columns from acting together.

British lines covering Lisbon.

It may not be unsatisfactory to close this general description of lines of intrenchments with a short account from the invaluable Memoranda published by Colonel Jones,* of the works executed before Lisbon by British engineers, between the years 1809 and 1812, for the purpose of protecting that city and the meditated retreat of the army from Portugal. These celebrated works were enclosed redoubts disposed in two great chains crowning the heights which extend between the Atlantic Ocean and the Tagus: the first or exterior chain was situated about twenty miles North of Lisbon, or twenty-five miles North of Fort St. Julian, which forms the Southern extremity of the Peninsula, and was the proposed place of embarkation. This chain commenced at the point at which the Zizandra falls into the Atlantic; the works occupied the waving ridge of heights on the left bank of that river, and extended to about two miles west of Torres Vedras, terminating near the Western extremity of the Sierra de Monte Junto. At the mouth of the little river St. Lorenzo, about seven miles South of the Zizandra, the second or principal line of forts commenced; and these were constructed on all the salient points and eminences of the ridge of heights extending from the Sea to the Tagus, and passing close to Mafra, Montechique, and Bucellas; which lie successively Eastward of each other, and through which proceed three of the four great roads leading from the North to Lisbon. The fourth, or Eastern road, runs through Alhandra close to the Tagus. The whole country between the great roads is hilly and broken, and cannot be passed by an army with its artillery without much difficulty and delay; and, to secure the roads effectually on the principal ascents at the passes of Bucellas, Montechique, and Mafra, were constructed strong redoubts and batteries for artillery, so disposed as to enfilade the roads and concentrate their fire upon particular points of them, at which it was intended to form mines, deep cuts, or other artificial obstructions when they might be required. The ridge of Monte Graça was crowned by one large and several smaller works; and these, with the works at Torres Vedras, served as isolated outposts to the principal line just mentioned: blocking up the approaches, and giving time for the troops to occupy the line before they could be attacked in force. A chain of redoubts connected the works on Monte Graça with others forming part of the line, and situated on the ridge at Alhandra: to the South of this ridge the Tagus is not passable by an army; and therefore the works could not be turned by an enemy on the opposite side of the river. Along the North face of the ridge just mentioned, and near the summit, on an extent of two miles, there was cut an almost perpendicular scarp fifteen or eighteen feet high, every part of which was closely flanked by a covered musketry fire, and also by artillery in enclosed works constructed on the salient points of the heights: all the flanking works

* *Memoranda relative to the Lines thrown up to cover Lisbon in* 1810. By Colonel John T. Jones, Royal Engineers.

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were plunged into by larger redoubts on commanding interior peaks. Additional redoubts were, subsequently, formed between the ridge at Alhandra and that of the Sierra de Serves at Bucellas; and the valley between them was blocked up by an abattis with a covered communication in its rear. The front of this communication could be swept by artillery from the Alhandra heights, and closely flanked by musketry from some stone buildings in the sides of the valley.

In the whole line between the Ocean and the Tagus there were one hundred and fifty-two redoubts mounting, in all, five hundred and thirty-four pieces of artillery, while the army to be covered consisted of but fifty thousand men; a small number when compared with the extent of the line, which was equal to about twenty-nine miles, and required above thirty-four thousand men to garrison the works. But this vast developement is, in the present case, justified by military men on the ground of the extraordinary strength of the principal works, which is considered as rendering them in some respects fortresses. Colonel Jones, moreover, observes that not more than one-third of the works would have been required to be fully manned at any one period. The redoubts were generally adapted to the ground, and were of every capacity: the smallest was constructed for fifty men and two pieces of artillery; others could contain five hundred men and six pieces, and the great redoubt on Monte Graça required one thousand men and had twenty-five pieces. Some of the works were in the shape of star-forts, but it was objected to these that the defence of the ditches was imperfect; and the direct fire towards the front was insufficient. It may lastly be observed that there was an enclosed work on the height between St. Julian and Oeyras, near the proposed point of embarkation, with independent redoubts and batteries: the principal work was well flanked and required a garrison of one thousand three hundred and forty men.

Têtes-de-pont.

Works thrown up in front of bridges to cover and defend them, constitute what are called *têtes-de-pont:* their general disposition and shape may vary in a thousand ways, according to the nature of the localities and to the importance of the object. The works constructed to serve as a tête-de-pont are frequently ill-adapted to this object: being either too small to cover the bridges properly from the enemy's fire; or having so great a developement that a large portion of the army is withdrawn from active service merely to guard them. A tête-de-pont ought to be capable of effectually concealing the bridge; but it should require for its defence the smallest possible number of troops, in order that the disposable forces may be so much the more numerous. When the passage is one of importance, it may be expedient to give to the tête-de-pont the form of a line with intervals: that is, upon an arc of a circle whose radius is one thousand or twelve hundred yards, a disposition should be made of redans or detached bastions, flanking each other; and, in rear of these, and covering the immediate approaches to the bridges, a central work should be placed: serving as a redoubt so disposed as to batter the intervals between the retrenchments in front, defend their gorges, and afford a safe retreat to the troops when driven from the advanced works. A disposition of this nature will keep the enemy's cannon at a sufficient distance from the bridges to prevent any annoyance in passing the river. If the tête-de-pont is constructed upon a re-entering bend of the river, the redans or bastions may be placed in a straight line or one nearly so, which would improve the defence and lessen the extent of works. In this case, also, the redoubt of the tête-de-pont may easily receive a flanking defence from batteries established on the opposite bank, or on islands which are frequently found in the bends of rivers; and it is considered that, on this account, and because the bridge is more effectually concealed from the view of the enemy, a re-entering bend or elbow, the concavity of which is on the enemy's side, is the most advantageous place for a tête-de-pont.

See fig. 18.

The advanced works should be made capable of containing about two hundred men; their gorges should be secured by a row of strong palisades; and they should be provided interiorly with a small redoubt or blockhouse. Lunettes constructed thus carefully, and well fraised and palisaded, may be placed at greater distances from each other than those of ordinary construction, because being stronger in themselves, they stand in less need of immediate succour: their salients may be placed three or four hundred yards apart. A system of works of this kind, partaking of the nature of mixed *fortification*, would be well adapted to cover an important passage of a river; and the enemy, unable to carry them by assault, would be compelled to go through the formalities of a siege. Indeed, without these conditions, the army, which may have retreated through the intervals to shelter itself from the enemy's superior forces, would have to cross over to the opposite bank, and abandon to feeble garrisons the defence of the advanced works. These garrisons, too weak for a long resistance, would now betake themselves to a retreat, if such a measure were still in their power; the approaches would therefore no longer be covered; and all the advantages of the têtes-de-pont would vanish at the first appearance of the enemy. It is therefore necessary, in order to oppose an effectual resistance to the progress of the enemy, that the exterior works should have all possible solidity and strength.

When a tête-de-pont has not the defensive qualities that could be desired, and the retreat of the army to the opposite bank is a measure of necessity, it may be effected in the following manner. The retreating army is divided into as many columns as there are intervals between the advanced works; each column takes the direction of its allotted interval, and when it has passed the latter it deploys immediately in rear of it. Those of the columns which have not room for deploying either as a first or second line, immediately cross over to the opposite bank. The fire of the works will open as soon the space in front of them is sufficiently unobstructed by the retreating army. The infantry deployed stands now alone before the enemy; the advanced works being evacuated, and their garrisons retiring through the intervals of the divisions. The artillery and cavalry, with the exception of a few guns and squadrons, have already passed over the bridges. The infantry commences its retreat *en échellon*. As soon as the central redoubt is unmasked, its fire is opened to protect the retreat. When the enemy is master of the field, the garrison of the redoubt retires; the victors now enter tumultuously in the abandoned work and hasten to get possession of the bridges; but they are stopped by the last tambours made of strong palisades, and defended by one or two companies of grenadiers, who have volunteered to dispute the spot until the bridges are destroyed. When their object is gained, these companies either surrender themselves prisoners, according as they may have re-

Fortification.

ceived instructions, or make their escape by swimming or by boats placed at hand for the purpose.

The redoubt, or central work of a tête-de-pont is an important part which ought not to be negligently constructed; since it immediately covers the passage, and ensures the retreat of the last defenders of the works in advance. The redoubt ought, therefore, to be made capable of offering the greatest possible obstacles to the attack. It usually consists of two or three bastion fronts; the wings being defended by batteries thrown up in rear on the opposite bank of the river. The passages are made in those wings: they should be about twenty yards wide, and masked by traverses thrown up within. Inside of these redoubts, others made of timber in the manner of tambours should be constructed to cover the immediate approach to each bridge: the utility of this measure must be apparent from the foregoing description of the manner of effecting the retreat. Care must likewise be taken when constructing a tête-de-pont, to throw up one or two batteries for destroying the bridges, in the event of the enemy's unexpectedly forcing the central work, and not giving time to cut them away or burn them. Fig. 18 represents a grand tête-de-pont, where all these conditions have been observed. It often happens that there is but one bridge to be covered; in this case the central work may be much smaller than the preceding one, and be composed of a single bastion front connected with the bank by long branches; or it may be a mere bonnet de prêtre, or even a lunette defended from the opposite side. These last two are most usually executed in petty warfare: but nothing can be fixed respecting their dimensions, both these and their shape being always determined by local circumstances.

CHAPTER V.

Details of Construction.

On the relief of field-works.

Having described the shape or outline of the principal works executed in the field, it will be necessary to say a few words respecting their relief, before we proceed to show the manner in which they are constructed. A good relief is not less essential to an intrenchment than a well-combined outline. The most usual height given to the covering masses of field-works is seven and a half feet: this height is chosen in order that a man on horseback may be unable to see over the parapets into the work. Parapets are nevertheless often made of less height: for instance, six feet is not a bad relief if there is no apprehension of a cavalry fire; and intrenchments constructed hastily to procure cover for a detachment, are often made no higher than four and a half feet: but in this case, as there would not be sufficient cover, it is necessary to excavate about one and a half on the inside. The required solidity of the work, as we have already said, depends upon the nature of the projectiles which it may have to resist. But whatever be the thickness of the parapets, it is necessary that the earth excavated from the ditches be sufficient for the formation of the covering mass. Whence it follows, that the breadth and depth of the ditches must vary with the height and thickness of the parapets. It may be well to repeat, that the means usually at hand for the construction of field works will not permit a greater depth to be given than twelve feet to the ditches; and, in order that the latter may be at all serviceable, they ought not to be less than six feet deep. Hence, in every field-work constructed solely with spade and pickaxe, the depth of the ditch will vary between six and twelve feet, and these dimensions may be considered as their limits. In calculating the depth and breadth of a ditch according to the dimensions of the profile of the covering mass, it must be remembered that the earth generally augments in volume when loosened from its natural bed; and that this increase of volume sometimes amounts to one-tenth or one-twelfth.

Profiles.

Profiles cannot in moments of need be calculated with mathematical exactness: it would therefore be well if every officer carried with him in his pocket-book a ready-made Table of the dimensions of ditches corresponding to certain given profiles. If unprovided with such a Table, the following approximation will be found quite adequate to the purpose. Ascertain the superficial contents of a vertical section taken perpendicularly to the length of the intended parapet or covering mass. Then assume the depth of the ditch, which will generally be the same as the height of the work. Divide the contents of the profile by that depth, and the result will be the required breadth. For instance, if the ditch is to be six feet deep, and the surface of the profile should contain one hundred and eight square feet; the required breadth will be eighteen feet for the upper part of the ditch. This expeditious formula, indeed, supposes the ditch to be dug vertically down without slope; that there is no augmentation of volume; and that the ditch has no greater developement than the parapet: all which suppositions are contrary to truth. But the ditch being dug with a slope, the surface of its profile will be diminished; and this decrease of surface will partly compensate for the increase of volume and excess of developement, so that the result will be sufficiently correct for actual practice. Or, if the eighteen feet above found be considered as the mean breadth of the ditch, and if there be added to it such an aliquot part of the given depth as is expressed by the proportion of the breadth to the height of the intended slope, the sum will express the true breadth of the ditch at the upper part. Although we have generally spoken of six or seven and a half feet as the height of the parapets, it does not follow that, under some circumstances, still less may not be given to them; but then they lose much of their efficacy, unless the work is situated on an eminence; and if the height is less than four feet and a half the berm must be formed below the level of the natural ground, for the reason given in describing that part of the work. When parapets have more than the ordinary height given to them, it is sometimes impossible to direct their superior slopes upon the edge of the counterscarp. The latter must then be raised by a mass of earth sloping gently towards the country upon the prolongation of the superior slope; or, in other words, by giving a glacis to the work.

See fig. 19

When a work is traced upon the ground, that is, when strong pickets have been driven at all the angles and connected by ropes, or by furrows cut in the ground, two profiles must be set up on each line to designate the form of the parapet, and to point out to the workmen where they must throw the earth. If the face of the work is rather long, two profiles may not suffice; a third must therefore be added in the alignment of the former two. These profiles are made of fir laths when such are to be obtained: in which case they may be set up with all desirable perfection, representing exactly the shape of the parapet. In the first place, there should

be driven two strong square-headed pickets A and B, denoting the thickness of the parapet; against the first of these is nailed a lath AC, equal in length to the required height of the parapet; in like manner there must be nailed against the second picket a lath of indefinite length B; and then at the extremity C of the first, a transverse one, to which is given, by a quadrant, or a mason's level, or even by the eye, the inclination which may be deemed expedient: this done, it may be fastened at the proper point D. The superfluous length of BD must then be sawn off, and the fourth lath DE placed at an angle of 45° with the ground, by nailing it at D, and to the square-headed picket E. The banquette is profiled in the manner indicated in the figure.

Profiles may be economized by constructing them upon the angles; as then, one profile will serve for two faces. These angular or oblique profiles have over the square ones the advantage of designating more clearly the parapets of the works, which facilitates their construction. and obviates unnecessary removals of soil. Some degree of habit is requisite in the construction of these oblique profiles. After having driven into the ground pickets in a direction perpendicular to the magistral line of any face of the work at each extremity of such face, and at distances from one another equal to the horizontal breadths of the several slopes, as in the former profile; ropes or tracing lines are stretched upon the ground in the directions of the capitals at each salient and re-entering angle. Then, by a rope extended in a direction parallel to the magistral line touching any two corresponding pickets, intersections are obtained with the ropes indicating the capitals; and those intersections are marked by other pickets. These will be the places at which are to be raised the vertical poles or laths for determining the form of the profile; and the same heights must be given them as would have been given to the parts of the perpendicular profiles before described. When two angular profiles are set up they will serve for determining those at all the other angles. It may be well nevertheless to establish here and there a square profile to rectify the oblique ones, and to guard against the errors which might creep in. When laths cannot be obtained, branches of trees, however clumsily shaped, may be used to mark the heights, and then with strings or cords the various slopes may be indicated by tying them to the ends of the branches. Besides, when it happens that such means are wanting, it is seldom necessary to model the parapet with great nicety; the essential thing being to get cover, and for this purpose a good relief will suffice, which may be had even without any regular profile. When all the profiles are constructed, the space to be occupied by the parapet becomes known; then there may be traced, at a foot and a half from the foot of the exterior slope, the line representing the edge of the escarp, and at a proper distance, that of the counterscarp.

Tracing of works.

In all the works of which we have given a description, the ditches are usually made of an uniform breadth throughout, provided the parapet has everywhere the same height and thickness; it would, however, be well to diminish the breadth of the ditches at the salient, and widen them at the re-entering angles; because at the former they have more developement than the parapets, and at the latter the contrary is the case. Whence it follows, that, in one instance, the workmen have more earth than they want, and in the other a deficiency, if in aligning the counterscarp, the precaution here suggested has not been taken. Hence, then, the counterscarps of flanked works will not be made parallel with the escarp, but be closer to it at the salients. The exact degree of this approximation at the salients cannot be indicated; and must depend upon correctness of eye and judgment in an officer. In any case it will be better to contract the ditch too much, than to be troubled with a surplus of soil which would exceedingly embarrass the work, and must ultimately be conveyed away to a distance with much labour. It seldom happens that an officer has time to profile a work before the workmen are set about it: the latter are usually placed at his disposal before the work is traced, and he himself conducts them to the ground. Whilst they are resting, he quickly determines his outline by picketing the angles; and as soon as he has approximately fixed the middle of his ditch, he places his workmen there, telling them to what depth they may begin by digging upon a breadth less than the presumed one of the ditch. Whilst the men are doing this, the officer reverts to his tracing; constructs his profiles; makes his little calculation to ascertain the breadth of his ditch; and finally traces with the pickaxe the lines of escarp and counterscarp. Care must be taken to round off the counterscarp at the salients by using the breadth of the ditch as a radius, and the angle of the escarp as a centre.

Distribution of workmen.

The disposing of the working parties in such order that the men shall not embarrass one another, and that the work shall advance in an orderly and expeditious manner, is a most essential object. The work is portioned off into lengths of nine feet, measured along the centre line of the ditch. In each of these divisions is placed a party of five men, one provided with a pickaxe and the other four with spades. Two of the spademen are placed by the side of the pickman, and the other two are placed upon the berm to pitch the earth further in. Besides these five, a sixth spreads the earth upon the mass of the parapet, consolidates it with a rammer, and forms the exterior slopes; this man uses alternately the rammer and spade. Hence there will be six men in each party, being at the rate of four men per fathom, measured along the middle of the ditch. Besides these workmen, sappers, gunners, and other intelligent soldiers should be employed in making the revetments and other delicate details. A corporal may have charge of five parties, and a sergeant may command the fatigue party of the whole redoubt. In sinking the ditch, it has been recommended to excavate as much at first as two or three feet in depth with a breadth less than that of the whole surface of the ground, marked out for it by one or two feet measured from both the escarp and counterscarp, and to cut the sides down vertically; then to excavate an equal depth with a breadth less than the former, by retiring a foot or two from the sides before cut down, and again to cut vertically, and so to continue till the required depth is obtained, by which the sides of the ditch will have the form of steps. These steps are necessary to ascend and descend by; to prevent the workmen from excavating too much; and to assist in fixing the slopes by the height and breadth given to the steps. When the whole mass is excavated, the steps are cut away; first with the pickaxe, and next with a flat spade when neatness is required. The good soil should be carefully preserved for the slopes of the parapets, which must otherwise be formed with earth got from beyond the ditch: every kind of soil not being

equally good for uniting and becoming compact under the blows of the rammer. When works are very hastily constructed, it is impossible to put away the good soil; on the contrary, the covering mass must be formed as fast as possible with whatever comes to hand, and then the stratum of vegetable soil, which is generally the best, is covered over by that of an inferior quality: if the latter is too gravelly, the upper layer must be removed within the terreplein to be used afterwards in forming the exterior of the parapet. In making choice of the site of the work, it will be well to avoid as much as possible rocky and gravelly soils, only covered at top by a slight stratum of good earth. From the commencement of the work means must be provided to carry off the rain-water, which, without this precaution, would stagnate in the terrepleins, and render them uninhabitable. When the work to be constructed is open at the gorge, a drain may be made towards the latter, and the terrepleins on each side may have a gentle slope towards the gutter. But when the work is an enclosed one, a small drain must be made either with flat stones or boards underneath the parapet in that part of the work which is the lowest; taking care to let the spout project sufficiently beyond the escarp to prevent the latter from being furrowed by the stream. It is reckoned that one man may (in easy soil) dig up eight cubic yards per diem of eight hours' work; but this is the case only when the excavation is near the surface, and that one throw will project the earth into the mass of the parapet: when digging rather deeply and in a strong soil, the average quantity of work is six cubic yards per man; and frequently only three or four yards per man, when it is necessary to place a relay upon the berm.

Manner of defilading fortifications.

When a work is not commanded by any eminence within range of musketry or artillery, the plane of site may be considered as horizontal, and as coinciding with the ground on which the work is constructed; and no greater height need be given to the parapets than will suffice to conceal the interior from an enemy standing on the same level plane. But should the enemy be enabled, from any position possessing superior elevation, to direct a plunging fire into the interior of a work having only the relief above supposed, it is evident, that to render such a work habitable, it would be necessary to raise the parapets on the side next to the enemy until they should conceal the terreplein from his view. In determining the heights which should be given to the parapets that they may thus cover the interior, consists the Art of Defilading: which, for permanent fortifications, requires that accurate profiles of the ground within and about the site of the intended works should be taken, by going over it in various directions with the spirit level. These profiles enable the engineer to determine the height of the several inequalities of the ground with relation to an imaginary plane of site passing obliquely to the horizon through the summits of the commanding height on any one side, and coinciding with the terreplein of the work on the opposite side; and thus he has it in his power to compute the elevations which his parapet should have above the ground whereon they are to be raised, in order that they may possess the same command over the oblique plane that they should have had over a horizontal plane if not commanded. But in Field Fortification, where the haste of the service renders such levellings and computations impossible, it is necessary to have recourse to a more simple method of defilading the interior of works; and this we now proceed to describe.

When the work is to be defiladed from a hill in front, or when the line of fire from thence is nearly perpendicular to the direction of the parapet, a tall picket must be set up on the tracing of that parapet at the part which is nearest to the hill. Then, a visual ray directed to a point at the gorge or rear face of the work, eight feet above the ground, from a point four or seven feet above the commanding hill, according as the work is to be defiladed from artillery or musketry, will intersect the picket in a point indicating the height to which the parapet is to be raised on that side of the work. It is evident that this visual ray representing a line of fire from the enemy's position on the hill, a parapet the height of which is thus determined will defilade all the interior of the work. But if from this operation there should result a height greater than can be given to the parapet with the means at hand, the parapet must be raised only as high as such means will permit; and then the interior of the work must be more completely defiladed by a traverse, the situation of which may be thus determined. Find a place on the terreplein of the work where a visual ray from the point before mentioned, on the summit of the hill and passing through the crest of the parapet towards the interior, will meet one at eight feet above the ground; and at the spot thus formed the traverse must be raised: then all the space between the parapet and the traverse will be defiladed by the former, and such a height must be given to the latter as will defilade the part in its rear. This height may be found as that of the parapet was found in the former case. If the height which can be given to the traverse should not suffice to defilade the whole of the terreplein in its rear, the situation of a second traverse must be found by the same process as before. Should there be a parapet on that side of the work which is furthest from the hill, it will be necessary also to put the defenders of that parapet below the plane of defilement, in order to protect them from the reverse fire of the enemy on the hill. For this purpose the visual ray which determines the height of the first parapet or traverse must be directed from the enemy's fire-arm on the hill, not to a point eight feet above the terreplein of the work, but to one eight feet above that of the banquette on which those defenders are placed: the relief of the parapet on this side having been previously determined by the command which it ought to have over the ground before it.

If such a work as a redan or a bastion presents its salient angle to the rising ground from which it is to be defiladed, the height of the parapet at that angle must be determined, as before, by two visual rays, directed to points eight feet above the ground at the lateral extremities of the gorge; and the crests of the parapets of the two faces may lie in a plane of defilement with which those visual rays coincide. Should such a work be commanded by hills opposite to both faces, the reliefs of the parapets must be determined by the coincidence of their crests with two planes of defilement which intersect each other in the interior of the work at eight feet above the terreplein, and pass through the summits of the hills; and at the line of intersection a traverse must be raised, the height of which may be found by visual rays directed to points, each situated at eight feet above the banquette, from the hills in front of the opposite faces. This traverse should pass through the salient angle of the work, that it may defilade the whole

of the interior on each side of it; but its tracing on the ground is not necessarily rectilinear. If the two planes of defilement should not intersect one another above the terreplein of the work, two traverses must be raised where those planes respectively approach within eight feet of the terreplein. Let it be observed, in the last place, that when a work is entirely surrounded by heights it may, with most facility, be defiladed by a pair of traverses crossing each other in the interior.

Formation of the revetments:

Earth will not support itself at the interior slope upon so small a base as it is necessary to give it so that the troops may approach the parapet with ease when firing. It is therefore requisite to revet that slope; and this is usually done with fascines, hurdles, sods, or sand-bags.

with fascines;

Fascines have been already described under the head of siege operations. When employed to form a revetment for the interior of works, the fascines or saucissons are disposed horizontally; the first is half buried in the banquette and is fixed by three pickets driven in with a mallet: these pickets are three feet long. The second row of fascines is placed rather within the top of the first, in conformity with the required slope, taking care to fasten each fascine with three pickets or stakes, the two extreme ones being driven through the fascines underneath in the direction of the slope, and the third in a direction perpendicular to the slope, in order to connect the revetment strongly with the soil. The Austrians substitute for the last-mentioned picket a strong twig with a hook at one end like an anchor, which embraces the whole fascine, and is then fastened at the other end to a stake driven into the mass of the parapet, and covered over with earth: this gives great solidity to the revetment. Fascines are laid in the same manner as bricks or stones in buildings, with the ends of one course over the centres of the other; and at the angles they must be twisted round to avoid any disjuncture. When five courses of fascines or saucissons have been laid down, the upper course nearly reaches the crest of the work; this may then be covered with sods laid flat, with the grass uppermost, to connect them with the earth of the parapet. The exterior slopes of parapets also are sometimes revetted with fascines, when great stability is required; but in this case the fascines should lie in vertical planes against the slope, with the lower ends fixed in the ground at the foot, lest the enemy should use them as steps to ascend the parapet.

with hurdles;

A sort of hurdle revetment also is sometimes formed by planting strong pickets in the direction of the slope, and then weaving or interlacing flexible branches round them. These branches are fastened at the top of the revetment to the heads of the pickets, in order that the hurdling may not detach itself from the parapet.

with sod or turf;

When sods are used for revetting, they are cut in a rectangular shape, two feet long, one foot broad, and six inches thick. They are laid by headers and stretchers, ends over centres, and grass undermost. This last precaution is necessary, in order that they may lie flat, and that they may the more easily be pared with the spade when the revetment is built; and a stake ought to be driven through each sod to fasten it to those which are underneath. To ensure solidity the revetment should be built only in proportion as the work itself advances, care being taken to ram the earth well against the interior sides of the sods. When the revetment is finished, all the rough ends of the sods are shaved off with a spade having its edge formed in an arc of a circle, and sharpened that it may cut off the roots more easily. The sod revetment may be executed with the greatest perfection; and it is always employed in preference to any other where nicety is required. One man may lay sixteen square yards of sod revetment per diem of eight hours' work, when he has the sods ready at hand.

with sand bags,

The interior of a work is also sometimes revetted with what are called sand-bags: these are sacks which, when filled with earth, are about two feet long, one foot broad, and seven inches thick; they are disposed in horizontal courses with their sides and ends following each other alternately in each course like bricks in a wall; and the usual precautions are taken to break joint, or that the junction of every two bags in one course shall be over the middle of a bag in the course below it. This kind of revetment is, however, objectionable, being liable to be washed down by heavy rains; and unless well tarred, the bags burst when very wet.

or with mud.

But it often happens that there are neither woods nor meadows in the neighbourhood from which fascines or turf can be extracted. In such cases the flooring of the nearest houses may be taken up and the materials used for the revetments. If this means be also wanting, a kind of mortar may be made by mixing the most binding earth that can be found with chopped straw, &c.; and this being wetted and well rammed will have such tenacity, as to allow the required inclination to be given to the parapet. In no case must the revetment be made of either masonry or loose stones. The splinters which the shot would produce on such revetments, are more to be apprehended than the shot themselves; because as they fly in every direction, there are no means of finding shelter from them.

Revetment of escarps with trunks of trees or planks.

The slopes of the parapet are not those which alone require a revetment: the earth on the escarp of the ditch, in some cases, requires support; as when, the work being of importance, the soil is not sufficiently stiff to remain at a slope the base of which is one-half or one-third of its height. The escarps of works have sometimes been revetted with trunks of trees placed horizontally; but, disposed in this way, they offer facilities to the escalade, being somewhat like a flight of steps. It would therefore be better to place the trunks contiguously, and on their ends, with a gentle inclination towards the work. But the best mode of all is to revet with strong planks supported by frames, the ends of which are buried in the earth. The figure will sufficiently show the nature of this contrivance without further explanation. See fig. 20. It must nevertheless be remarked to the disadvantage of this carpentry work that, as the tie beams necessarily run into the natural ground, the parapet cannot be modelled before the revetment is finished; it therefore follows that the earth must be heaped up at a distance from the berm, till it can be used in building the parapet. This may be considered as an argument that revetments of the escarp scarcely belong to field fortifications properly so called, but rather to those of a mixed nature.

Of the accessaries to field-works.

When cannon are placed in a field-work, care must be taken to avoid as much as possible making embrasures or port-holes in the parapet for the cannon to fire through, as they weaken the parapet considerably, are marks for the enemy's shot, and facilitate his entrance into the work at the time of the assault: the small opening which it is allowed to give them, moreover, limits exceedingly the space through which the guns should traverse. It would generally be preferable therefore that the artillery should be placed so that it may fire over the parapet.

Fortification.

The mass of earth or platform thrown up for this object is called a *barbette*. Its surface ought to be about two feet and a half beneath the crest of the parapet; but its extent will depend upon the number of guns for which it may be intended. A field piece with its appurtenances requires a space of about eighteen feet by fifteen. Hence the platform or terreplein of the barbette destined to contain one gun, will be a rectangle having its length, in a direction parallel to the parapet, equal to fifteen feet; and, in a direction perpendicular to it, eighteen feet. The ascent to the terrepleins of barbettes is made by ramps or inclined planes, the base of which should be equal to six times their height; and their breadth is obviously regulated by the length of axletree of the gun-carriages which are to pass over them. It is not unusual to provide against the danger of a side or enfilade fire, by erecting on each side of the guns a traverse six feet high at least: and in order that these shall occupy the least possible space, it is usual to make them of gabions filled with earth, placed in two or three rows on the terreplein, and having two courses in height. Gabions have already been described in the attack of fortresses: when used for traverses, and generally for intrenchments, they should be three feet high and two feet in diameter.

Entrances into field-works.

The entrance into a field-work is cut through the parapet, and the sides are kept as steep as possible to diminish the exposure of the interior of the work. The entrance is not made wider than is absolutely necessary to afford a passage for the cannon; and it is closed by a barrier or *cheval-de-frise*. A cheval-de-frise is a beam or prism of timber, the section of which is either a square or hexagon, with spears passed through it.* It may here be remarked, by the way, that for the defence of works, chevaux-de-frise are also placed on the berms, in the ditches, or on the exterior. They are placed in line, and are linked together by means contrived for the purpose at each of their ends. The prism is usually about twelve feet long. The spears or staves are about six feet long and two inches in diameter, and are made either round or square. This is rather a complicated machine, and one which would require proper materials for its construction, and artificers accustomed to that kind of work. The facility also with which chevaux-de-frise are destroyed by a few rounds of artillery, has caused them to be disused of late: so that they are no longer carried about with armies, and are scarcely ever employed but as barriers at the entrances of a field-work. The required communication between the counterscarp and such entrances is made by throwing four or five beams across the ditch, and placing boards or planks transversely over them. In a moment of danger these are pulled away, and converted if necessary into means of strengthening the entrance barrier. When the ditch is more than twelve feet wide, a trestle may be placed in the middle to support the beams. It may sometimes happen that the bridge is upwards of twenty or twenty-four feet long; in these cases more trestles must be employed, and care must be taken not to place them at a greater distance from each other than twelve feet. It is absolutely necessary that the powder of a field-work should in some way or other be sheltered both from damage by rain and by the fall of shells. When therefore time and means are allowed, a splinter-proof magazine may be constructed in an appropriate part of the work: for instance, under the mass of a large traverse. But should these be wanting, a good practice, and one which has often been tried with success, is to bury the powder in the mass of the parapet, having placed it in any common box which may have served for the transport of ammunition, the cover side serving as a door, to which a lock may be put if one is at hand; but whether or not, a sentry is placed near it to prevent accidents.

Chevaux-de-frize.

Bridges over the ditches.

Powder magazines.

CHAPTER VI.

On the Means of adding to the Strength of Field-works.

The ditches of field-works being usually of an inconsiderable depth, can hardly be regarded as efficient means of stopping an enemy: for if they are but six feet deep, (and the haste with which such works are usually thrown up will rarely permit them to be deeper,) he will easily jump into them, loaded as he may be with arms and knapsack. The dead angles also of those ditches, where the enemy will be perfectly secure, will give him time to breathe, rally, and form for the assault. It is therefore necessary to place obstacles upon the approaches to those points. Now as the salients are in all works the weakest points, all the resources of art must be employed to retard or arrest the enemy's march towards them, to throw him into disorder, and keep him a long time under the fire of the work. The best of all obstacles is an *abattis*: which is a barrier formed of strong interlaced branches of trees stripped of their leaves and smaller parts, sharpened at their extremities, and presenting outwards a cluster of points. They are fastened to the ground at the thick end, and screened from the enemy's sight by an advanced glacis, the slope of which is upon the prolongation of the crest of the parapet; the earth requisite for the purpose is taken from behind it upon the production of the slope of the original glacis. Trees or branches thus placed can with difficulty be removed by hand; and cannon shot produces but little effect in deranging them: the only effectual method therefore of destroying them would be to set them on fire. *Trous-de-loup* are excavations in the form of inverted cones or inverted pyramids, six feet deep and six feet wide at top; they are placed in chequer and six feet asunder, and are sometimes covered with furze or light branches, to conceal them from the sight of the enemy. Trous-de-loup are excellent means of arresting the march and breaking the ranks of the assailants. The earth resulting from the excavation being piled up on the sides, renders the ground exceedingly uneven, and prevents the formation of any kind of order in the attack: but, as it is attended with the evil of raising the ground two or three feet, trous de loup are only admissible where the parapets of the works have a command of seven or eight feet over the country: otherwise, it is necessary so to strew the earth about as to form no sensible elevation. At the bottoms of these holes strong stakes are driven in with sharp points upwards; their use is to prevent the enemy from taking cover in them against the fire of the works. It is thought however that active riflemen would make use of them as covers, from within which they might pick off all who should show their heads above the parapet. Trous-de-loup may be employed in several cases: as first, in front of lines, to render their access more difficult and retard the march of the attacking columns. Secondly, against cavalry when any particular part of a front requires to be screened from its attack. And lastly, Guy de Vernon

Abattis. See fig. 21

Trous-de-loup.

recommends them strongly to be employed in the bottoms of the ditches of field-works.

Crows' feet. Crows' feet are pieces of iron with four points diverging from a centre, and so made that whichever way the mass falls, one point will always be presented upwards. They were formerly very much used, being strewed over roads where the passage of the enemy's cavalry happened to be unavoidable. Some recommend strewing them in quantities over the glacis or on any of the approaches to field-works: but for this purpose they are not so good an expedient as small pickets or stakes planted in great numbers, and projecting six or eight inches above ground. The harrows used by labourers would be of great service, if buried so as to leave only their points above ground.

Pickets and harrows.

Inundations. Whenever local circumstances permit the ditches to be filled with water to the depth of five or six feet, this means of defence should not be neglected; as not only the defect of dead angles will be completely remedied, but the enemy will be forced to employ more than ordinary means to approach the work. If a small river or rivulet passes within musket range of the work, the difficulty of access to the latter may be increased by throwing up some dikes across the course of the river, thereby spreading an inundation over the adjacent ground. These dikes are so placed as to be enfiladed or flanked by the fire of the work; and when time and workmen are not wanting, the most exposed amongst them may be covered or supported by a small redan to prevent the enemy from arriving at them and draining off the waters of the inundation. Experience has proved that a good dike should not be higher than nine feet: hence, from one dike to another, when several are used, the difference of level between them should be only four feet and a half, in order that the most shallow parts between two dikes shall not be fordable. Therefore, after fixing the place for the first dike, that of the others will depend upon the natural slope of the waters, which must be determined by levelling, or ascertained by information obtained from the neighbouring millers. The level of the second dike will be placed four feet and a half lower than that of the first; the third as much lower than the second, and so on with the rest. Hence it follows that this kind of defence is inapplicable to a mountainous country, because the slopes are too great: it is equally so to a country where the bed of the river is not sufficiently confined, and has its borders too far apart; because the dikes, in this case, would require too considerable a length, which would entail extraordinary labour in the construction, and difficulty in the defence.

It is impossible to fix a limit for the length of a dike, because its construction depends upon the means at disposal. In some cases a dike one hundred yards long would appear a prodigious undertaking: in other circumstances the construction of such a dike would be sufficiently practicable. But as neither the profile of a dike nor the length of its fall for the evacuation or running off of the superfluous water are dependent upon its length, some details upon the subject may be given. When a dike is not liable to be battered by artillery, a thickness at top of four feet and a half will suffice, supposing the dike to be made, as it most generally is, of earth. The earth may be taken from the lower or ebb side; and if it be not sufficiently binding and lets the water filter through it, proper earth must be brought from the neighbouring country wherever it may be found. This will augment the trouble, but is indispensable for the goodness of the work. The best way to prevent filtration is to line the inside of the dike with clay. When the dike is exposed to cannon its summit ought to be proof, that is, about nine or ten feet thick. Its natural slope may be given to the earth on both sides the dike; but for greater perfection, the upper slope, that is, the one on the flood side, should be made the gentlest, by giving its base twice the length of the dike's height; to avoid the shock of the stream and diminish its pressure.

If after constructing the dike with earth according to the profile above indicated, the waters were allowed to rise above it and flow over the whole of its length, it would not be long before the whole dike must be destroyed, supposing the current were at all rapid. To avoid this inconvenience, a space is left eight or ten inches lower than the rest of the dike, and of sufficient breadth to allow a free passage to all the water of the stream. This part forming a cavity on the top of the dike, and constructed more solidly than the rest, is called the fall or deversoir. This fall is constructed with fascines, that is, after building the dike to a certain height, a double revetment of well picketed fascines is commenced: this revetment must not only cover the top of the fall and the ebb side slope, but must extend underneath, forming a bed to break the fall of the water and prevent its undermining the foot of the dike. With respect to length, this bed is made to extend a little beyond each extremity of the fall, in order that it may more completely fulfil its object. To give greater solidity to the bed of fascines, the tops of the pickets which are driven through the mass, may purposely be left a little above ground, and have hurdle-work interwoven round them. The pickets or stakes ought to be four feet and a half long. The same hurdling might be made on the revetment of the fall; but if this should appear too laborious, the extremities of the fascines should at all events be secured by others placed crosswise and strongly picketed into the first. The cheeks of the fall are likewise revetted with fascines, which are placed at right angles with those of the top of the fall and picketed into them. See fig. 22.

When any part of the ground about the accesses to the work is low and marshy, but destitute of such currents of running water as would permit an inundation to be formed, holes or trenches five or six feet deep and as many wide may be substituted. These holes and trenches will effectually stop the enemy; and he will be obliged to fill them up before he can arrive at the counterscarp which they cover. The above-mentioned breadth will be quite sufficient to render them impassable for men loaded with arms, ammunition, and knapsacks. The earth excavated must be carefully and evenly strewed about, both to prevent its forming small islands which would assist the assailants, and because any rise of ground, in the vicinity of a field-work may be detrimental, owing to the small relief usually given to the latter. If the localities be such as offer to the enemy the facility of draining the inundation or sheet of water, the holes and trenches above mentioned may be multiplied, as they will contain water and be a serious obstacle even after the draining is effected.

Palisades. Palisades for field-works are made of strong branches or rather trunks of small or middle-sized trees, split into two or four parts, and generally cut into triangular prisms having each side six or seven inches broad; but whether they are used in their natural round state or

Fortification.

sawn into prisms or split in two, their efficacy is the same. Their length is nine feet, and they are sharpened at the upper extremity. The best place for palisades is at the foot of the counterscarp: because they are there most screened from the enemy's shot, and embarrass him most in his attempt to get into the ditch. If the palisades were placed contiguously, forming a *palanque* for the defence of the ditch, it would then be necessary to put them at the foot of the escarp; but when merely employed as an obstacle, which is most generally the case, they should be placed as above mentioned at the foot of the counterscarp. To plant palisades, a trench is dug three feet deep, and as narrow as possible; and in it they are placed three or four inches asunder. The earth is then well rammed down round them so that they shall be firm; and they are united at top by a riband or cross beam, against which each palisade is nailed. It would be still better if they were likewise fastened at bottom to a cross beam buried in the ground, for this would utterly prevent them from being torn up separately.

fig. 21. *Fraises* are nothing more than palisades placed horizontally or slightly inclined to the horizon, with their points downwards: they are usually placed upon the summit of the escarp, and then, notwithstanding the precaution of throwing up a glacis to cover them, they are soon destroyed by the enemy's cannon. Nevertheless great advantage is gained when he can be forced to do this: for during the whole time he is so employed, his fire, which is ricochet, is returned with interest by the artillery of the work with full service charge. The inclination given to fraises is intended to prevent the grenades, which are thrown into the ditch, from lodging upon them. Fraises must be placed as nearly contiguous as possible that the enemy may have the more difficulty in cutting them down with the hatchet, or in sawing them off. The placing of both palisades and fraises is a subject which merits to be well weighed: there being instances in which instead of opposing, they have contributed to facilitate the assault.* The length of the fraises ought to be at least ten feet and a half, in order that they may project four feet and a half beyond the escarp: about one foot and a half rests on the berm; and the remaining four and a half feet are buried in the mass of the parapet. They are nailed to a cross beam sunk into the berm; and that they may be firmly connected, another cross beam buried in the parapet unites their superior extremities.

Fougasses are perhaps the best of all means of stopping the impetuosity of an assailant: but unfortunately they cannot in every case be employed. When the besieger is aware that the work is provided with fougasses, and this he should be suffered to know, his timidity and circumspection will be extreme. Soldiers who have once witnessed the springing of one of these small mines, are in continual apprehension of explosions; and a hidden danger which they cannot anticipate produces upon them a much stronger apprehension than they are susceptible of feeling at perils of a more serious nature, when openly encountered. The effects, indeed, which mines produce upon the *morale* of assailants are perhaps the greatest advantage which they afford to the defenders. To establish a fougass, there should be buried, at the depth of a few feet, a box containing three or four loaded howitzer shells, or else about twenty pounds of powder. This box is communicated with by a wooden trough, which is likewise buried in the ground, and is destined to convey the fire to the charge. In order to place it, a narrow trench is dug, of the required depth; and after charging the mine and laying the powder pipe in the trough, the lid is carefully fastened down. The trench is then filled up again with earth, taking care to ram it down well, and scattering about the surplus on the surface. The well or hole which has been excavated to contain the charge, is, after the latter has been placed, filled up with stones instead of earth, to render the effects of the fougass the more destructive. The trough passes down the counterscarp under the bottom of the ditch, through the thickness of the parapet, into the interior of the work. It is sometimes made to stretch across the ditch, and is then supported by trestles; but this arrangement exposes it to continual accidents. If the box containing the charge be likely to remain long under ground, it is necessary to calk and tar it, as well as the trough, to preserve their contents from damp. Great care must be taken to guard against precipitation when about to spring a fougass, otherwise the chances are that it will explode before the enemy reaches the sphere of its effects. Fougasses are very advantageous at the angles of dead ditches, where they may be placed about ten feet asunder; and also at about ten or fifteen paces from the ditch, at those points over which the enemy is most likely to advance. The chief and perhaps only objection to them is that they seldom act at the precise moment when the enemy is immediately over them; unless therefore there be placed an abattis or some such obstacle to retard him there until the explosion takes place, his destruction by this means will be very doubtful. See fig. 21.

Defence of dead ditches.

When an enemy succeeds in getting into the ditch of a field-work destitute of flanking defences, he is perfectly safe from every thing but hand grenades; and it is not always that a supply of these can be commanded. It is therefore of importance that means should be employed to obviate so great an evil. If the work is a lunette, there may be placed a *palanque*, that is, a row of strong palisades across the ditch at the angles of the shoulder. Loop-holes are of course made at proper distances for the purpose of permitting a cross fire of musketry upon the salient. For a square redoubt, the simple palanques above mentioned are inadmissible because they defend only one side. Double palanques are therefore used, which are placed at two opposite salient angles, so as to sweep the whole of the ditch and have a cross fire upon the other two remaining angles. The palanques are covered at top with thick planking and fascines: and to screen them from fire, a bed of earth or manure may be laid over the top. A double palanque, or covered gallery of this kind, receives the name of *caponnière*. The descent into this caponnière is effected from the interior of the redoubt, by a passage cut underneath the parapet. The outer extremity of the caponnière is not made to reach the counterscarp; for, if so, it would soon afford the enemy a safe means of crossing the ditch. A portion of the counterscarp is therefore cut away at the head of the caponnière to isolate the latter. The small width in general given to the ditches, and the great quantity of timber necessary for the construction of the caponnières, are the reasons of their being seldom employed: they are, in fact, a means of defence which cannot be resorted to, otherwise than in cases where there is plenty of time at command, and timber in the neighbourhood.

Palanques. Caponnières.

* See Major Reid's translation of Col. La Marre's Defence of Badajos.

Fortification.

Counterscarp galleries of reverse fire.

Another expedient sometimes adopted, is that of loop-holed galleries underneath the mass of the counterscarp, for the purpose of having a reverse fire along the ditch. A communication is made from the interior of the work into these galleries of reverse fires, by a gallery driven underneath the bottom of the ditch. If the objection to the caponnières, arising from the great consumption of time and timber which their construction demands, be a just one, it applies much more strongly to these works which, for the same reasons, can be very rarely executed.

Interior redoubts.

The surest way to support the courage of the defenders, and consequently to increase the strength of a work, is to facilitate their means of retreat in case they should be overcome; and thus to procure for them a place of refuge, in which they may capitulate upon terms the more honourable in proportion as they have defended with gallantry the principal work. This may be accomplished by the construction of an interior redoubt, when the magnitude of the principal work will permit it. In forming such redoubts, care should be taken to dispose them in such manner that there shall not be a single point within the principal work undiscoverable by their fire; and their size must be adapted to the numbers for which they may be required to afford cover. If the principal work be one of a considerable extent, the redoubt may be made with earth, like an ordinary retrenchment, that is, with a parapet and ditch. But then a command must be given to it over the parapet of the exterior work, in order that the enemy when standing upon the parapet of the latter may be unable to see into the redoubt. The best kind of interior redoubt is that called a blockhouse, which we are next to describe.

Blockhouses.

Blockhouses are a species of retrenchment peculiarly adapted to woody countries: because the materials for their construction are found upon the spot; and as these countries are mostly mountainous, the enemy cannot without much difficulty transport his cannon with him. There is besides in such countries difficulty in finding a site whereon to construct a work of the ordinary uncovered kind, which may not be seen into and commanded by some neighbouring height. The plan of a blockhouse is usually that of a rectangle eighteen or twenty-four feet wide in the inside: but when it is possible to give it greater dimensions, its plan is that of a cross so that its fires flank one another mutually. The profile of a blockhouse will vary according as it may be liable to an attack of infantry merely, or of infantry with artillery.

Blockhouses opposed to infantry only.

In the former case its sides may consist simply of rows of contiguous trunks with loop-holes made in them three feet asunder. In order that the enemy may not be able to set fire to the blockhouse, he must be kept off from it by a ditch, the earth of which is piled up against the blockhouse as high as the loop-holes, and is moreover employed to cover the roof and form also a small glacis round the work.

Blockhouses intended to resist cannon.

The only difference between a blockhouse intended to resist artillery and that which has been just described is, that, instead of a single row of contiguous trunks of trees or piles, the former is constructed of a double row; the interval between them being filled with well-rammed earth as high up as the loop-holes, the whole composing a wall three feet thick. This work being of a more important nature than the preceding one, its inside dimension should be twenty-four feet, and the tie beams, owing to their length, must be composed of two pieces scarfed in the middle, and moreover supported by strong stanchions reposing on a groundsill.

American field-works.

But this description of the mode of erecting blockhouses, being confined to the usual practice of European service, would be incomplete without some reference to the peculiar construction and employment of similar defences in the forest warfare of North America. By the universal expertness of the backwoodsmen of that country in the use of the axe, works of the kind are constructed with astonishing rapidity, and rendered capable of opposing a formidable resistance. The Americans build their blockhouses, like ordinary log-habitations in their new settlements, of thick, horizontal trunks of trees, roughly squared; and several of these works, disposed like bastions at the angles of an area, in such order as to flank each other, and connected by a stockade, or curtain of close palisading of upright trunks of trees, loop-holed for musketry, compose a temporary field-fort of no despicable strength. Even when artillery can be brought against these works, their defenders, protected by interior traverses of earth, suffer little loss: while the blockhouses and stockades, being formed of green timber, do not easily admit of being breached; and may equally—as was proved in one instance, during the last war on the Canadian frontier,—defy any attempt to set them on fire with red-hot shot. Against mere musketry or an open assault, it is evident that, if well defended, the nature of such enclosed and flanked buildings can leave a garrison little to fear. The American blockhouses have sometimes an upper story, projecting sufficiently over the lower, to afford a plunging-fire, through the loop-holed floor, upon the assailants at the foot of the walls.

CHAPTER VII.

Attack of Field-works.

Having detailed the outline and relief of the various works thrown up in the field, and having pointed out the means by which such works may be rendered most difficult of capture, this Essay may appropriately terminate with a brief account of the manner in which intrenchments are attacked. If they are of little strength and importance, and unprovided with artillery, the assault is given without any previous cannonading. The light troops surround the post, directing upon the crest of the parapet a shower of bullets, to prevent the defenders from showing themselves, or at least to force them to fire precipitately and without aim. If nothing protects the access to the counterscarp of the work, the assailants jump into the ditch and prepare for the assault; a part of them remaining upon the counterscarp to keep down the heads of the defenders. When the troops have had time to breathe in the ditch, they give the assault, the men helping one another to climb up to the berm; whence, with a fresh effort they rush all together up the exterior slope, fire a volley, and then move at once upon the defenders to compel them to surrender. If, instead of the feeble intrenchment which we have just supposed, the work to be attacked were a large field fort, provided with an interior redoubt, armed with cannon, and strengthened with abattis, trous de loup, fraises, and palisades, destined, in short, for a long defence, the dispositions for attacking it would be very different. It must, in the first place, be reconnoitred, in order to ascertain, as nearly as possible, the nature of the obstacles to be overcome, the number

of cannon, and how they are placed, and likewise every detail of the ground about the work: in order that the measures taken for the assault may be properly executed even at night. Batteries are then constructed; and when ready, the howitzers commence ricochetting with shells, ploughing up the slopes of the parapets, and demolishing the fraises, disarranging and cutting up the abattis, dismounting the artillery, and destroying the troops: while the cannon fire with full charge and directly through the embrasures, converting the merlons into a heap of rubbish and dismounting the guns. When the cannon of the work is silenced, the light troops, who until then only occupied the intervals between the batteries, (not to obstruct their fire,) now surround the work, enveloping it in cross fires. The infantry, drawn up in as many columns as there are salients to the work, move forward, and the signal of assault is given. The abattis may arrest the progress of the troops until a passage be cut through it by the hatchets of the pioneers who march in front; and whilst this is being effected the battalions with supported arms remain exposed to all the fire from the work, without being able to answer it. The light troops however should, in the mean time, redouble their efforts to keep down the enemy's fire. The obstacle being overcome, the columns again move on in close order; the foremost men throw planks over the trous-de-loup, and prepare the way for the rest; when arrived at the counterscarp, the assailants descend into the ditch; cut away the palisades if there be any; rally; draw breath; and then rush to the assault, entering through the embrasures or passing over the parapet. In short, after a struggle, more or less protracted, the colours of the assailants are planted on the most elevated part of the intrenchment; the defenders, borne down by numbers, have ceased to resist; and withdrawing into the redoubt, there demand a capitulation, which a generous victor cannot refuse.

EXPLANATION

THE CHIEF TECHNICAL TERMS USED IN MODERN FORTIFICATION.

Abattis. A line of felled trees with their branches pointed towards the enemy, to obstruct his advance.
Advanced-work. Any defensive construction placed in front of the *covert-way*, but within range of the artillery of a fortress.
Approaches. See *Zig-zags*.

Banquette. A step to enable infantry to fire over a parapet.
Barbette. Any raised platform to enable cannon to fire over the parapet.
Bastion. A principal work in the enceinte of a place, composed of two faces projecting outwards, and two flanks.
Batardeau. A dam across the ditch of a fortress, to retain or let off the water at pleasure.
Battery. Any area on which cannon, mortars, &c. are placed to fire against the enemy's works.
Berm. A narrow path left between the parapet and edge of the ditch before it.
Blindage. See *Splinter-proof*.
Blockhouse. A covered building, generally of wood, for defence.
Body of the place. All works within the main ditch.
Bomb-proof. See *Casemates*.
Breaking ground. Commencing the trenches in a siege.

Camouflet, or *Stifler.* A small mine formed in the earth between two parallel galleries, to cut off the retreat of the enemy's miner.
Capital. A line imagined to bisect the projecting angle of any work.
Caponnière. A screened communication between two works.
Casemate. A vault of brick or stone, to cover artillery or to lodge troops, generally formed in the mass of the rampart, and always made bomb-proof: that is, of sufficient thickness and strength in the roof and sides to resist the effect of shells, projected from mortars.
Cavalier. Any elevated work in the *enceinte* of a fortress or in the trenches of attack, to give a command over the enemy.
Chamber of a mine. The excavation which contains the charge of gunpowder.
Chevaux de frise. Obstacles composed of horizontal beams, bristled with pointed stakes, sword-blades, &c.
Circumvallation. A line of works drawn round a fortress to exclude succour.
Coffer. A sunken *caponnière*, or trench for defence, generally covered, and lined with brick-work.
Command. The height of one work above another, or above the natural ground.
Cordon. The horizontal moulding which usually crowns the *revetment*, which see.
Counter-approaches. Trenches executed during a siege by the defenders, to outflank those of the enemy.
Counter-arches. Circular walls connecting the tails of *counterforts*, or arches built, in tiers, behind a *revetment* and between the counterforts, to resist the outward pressure of the rampart. See *Revetment*, and
Counterfort. An interior massive buttress of brick or stone, to strengthen the *revetment*, which see.
Counterguard. An outwork, covering the face of a bastion or ravelin.
Countermine. A mine used in defence.
Counterscarp. The exterior side of a ditch.
Countervallation. A line of works to prevent egress from a fortress.
Coupures. Traverses with a ditch in front, formed across the *terre-pleins* or upper surfaces of ramparts.
Covert-way. A communication round the works of a place in front of the ditch, and screened by a *glacis*, which see.
Crater. The excavation produced in the earth by the explosion of a mine.
Cremaillère line, or *Indented line.* A continuous parapet, forming a series of alternate branches and crotchets respectively parallel to each other. The interior slope of a parapet, when cut so as to form short faces alternately parallel and perpendicular to the capital of the work, is said to be *en cremaillère*.
Crest. The highest ridge of a parapet.
Crown-work. A double hornwork. See *Hornwork*.
Cunette. An open drain running along the middle of a larger ditch.
Curtain. The connecting line of rampart or parapet between two projecting works.

Dead-angle. That which is without flanking defence.

Deblai. The earth thrown out in the act of excavating the ditch.
Defilade. To screen the interior of a work, by a proper height of parapet, from the fire of the enemy.
Ditch. The excavation in front of a work, from which the earth to form the rampart or parapet is usually obtained.
Demilune, or *Half-moon*. See *Ravelin*.
Detached work. Any defensive construction placed beyond artillery range from a fortress.

Embrasure. An opening cut in the parapet for cannon to fire through.
Enceinte. The main rampart immediately encircling or surrounding the area fortified.
Enfilade. To sweep the interior of a work by a line of fire parallel to its front.
Entrenchment. Any defensive cover obtained by excavation.
Epaulement. In strictness, that elevation of earth which forms the wings of a battery, and covers the guns in flank: but the term is often, though improperly, used to signify the parapet in general of a battery.
Escarp. The interior side of a ditch.

Face. A line of rampart, usually forming one side of a projecting angle.
Fascine. A large faggot.
Fausse-braye. A low rampart in front of, and formerly attached to, the *enceinte*, which see.
Flank. The line of rampart or parapet between the face and gorge of any work, which defends either the collateral ground, or the fronts of works thereon constructed.
Flèche. A simple redan usually constructed at the foot of a glacis. See *Redan*.
Fougass. A small mine.
Fraises. See *Palisades*.

Gabion. A cylindrical basket open at both ends, planted on the ground to sustain the earth forming a parapet.
Gabionade. A parapet formed of full gabions.
Gallery. Any subterranean passage in mining.
Glacis. A parapet with a gentle slope terminating on the level of the exterior ground.
Gorge. The interval between the rear extremities of a work.

Hand-grenade. A small shell thrown by hand.
Hornwork. An advanced work composed of two half bastions and a connecting curtain.

Intrenchment. See *Entrenchment*.
Investment. The operation of confining a garrison within its defences.

Lines. A general term for any long extent of defensive works.
Lines of defence, are those supposed to be drawn from the projecting angle of a work to the interior extremity of the flank which is to defend it.
Loop-holes. Small apertures cut in walls or timber work for musketry.
Lunette. An advanced work in the shape of a bastion.
Magistral line. That which is first traced on the ground, or on paper, to express the contour of the plan of any work. In Permanent Fortification it is supposed to correspond to the cordon of the revetment.
Main-ditch. The principal ditch in a fortress immediately in front of the *enceinte*, which see.
Merlon. The portion of a parapet between two embrasures.
Mine. A subterraneous gallery and recess, to contain gunpowder for destroying, by its explosion, the enemy or his works.

Orillon. A projection at the shoulder of a bastion, covering the flank from exterior observation.
Outwork. Any defensive construction between the *enceinte*, or main rampart, and the ground immediately beyond the ditch.

Palanque, or *Palanka*. See *Stockade*.
Palisades. Rows of strong pointed timbers planted upright in the earth at small intervals. When not upright, and planted in the slopes of parapets, these are termed *fraises*.
Parados. A screen for defence against a fire in reverse, or behind.
Parallel, in a siege, is a trench nearly equidistant in all its length from the works of the fortress attacked.
Parapet, or *Breastwork*. The mass of earth which covers the fenders from the fire of the assailants in front.
Pierriers. Small mortars for projecting showers of stones, &c.
Place of arms. Any area destined for assembling bodies of troops; sometimes the parallels in a siege are so called.
Plane of defilement, is supposed to coincide with the crest of a work and the enemy's fire arm on the exterior ground.
Plane of site. The surface of the ground on which a work is constructed, if not commanded; when commanded, the plane is oblique to the horizon, and passes through the summit of the height.
Postern. A covered passage through the rampart into the ditch.

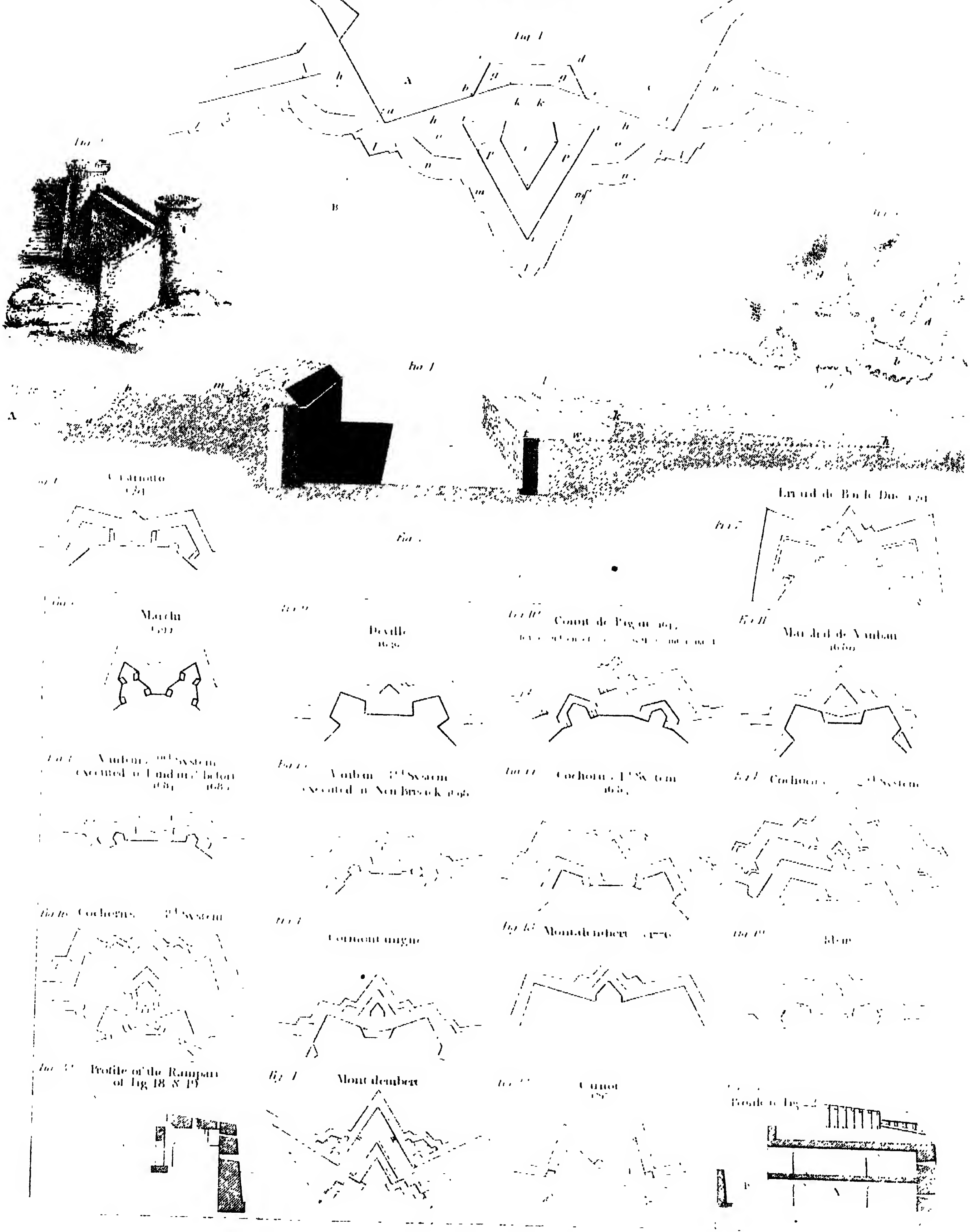
Ramp. An inclined plane for ascent or descent to a work.
Rampart. The mass of earth which encloses and screens the interior of a work, and on which its artillery and troops are placed in the defence.
Ravelin. A principal outwork, projecting in front of the curtain between two bastions.
Redan. A work consisting of two faces forming a projecting angle, employed to cover troops, or the entrance to a principal work; when two or more are connected by curtains they form lines of intrenchment.
Redoubt. Any enclosed work undefended by re-entering or flanking angles. Also, any work constructed within another, to serve as a place of retreat for the defenders of the latter.
Remblai. The mass of earth accumulated from the excavation of the ditch.
Rentrant or *Re-entering angle*. Any angle of a work of which the vertex points inwardly.
Retrenchment. Any work constructed in the interior of another to prolong its defence.
Revetment. Any wall sustaining the side of a ditch.
Ricochet. A mode of firing artillery, by which the shot is made to bound along a plane surface.

Salient angle. The projecting angle formed by the faces of any work. The ground in front of such angle is in common parlance called the salient of the work.
Sally-port. A gate beyond the ditch.
Sap. The process of executing approaches in siege operations behind gabions.
Saucisson. A long *fascine*, which word see. Also the tube or hose containing the gunpowder by which a mine is fired.
Shaft. The vertical descent into a mine.
Shoulder. The angle formed by the face and flank of a work.
Splinter-proofs. Blinds or covered buildings of carpentry or brick-work, of sufficient strength for protection against fragments of shells, grenades, &c.
Star-forts. Works enclosing areas and having faces disposed so as to form a series of angles alternately projecting and retiring.
Stockade, or *Palanka*. A row of trunks of trees or stout timbers, planted upright, close together, and usually loop-holed for musketry.

Tambour. A small enclosure of timber or brick-work, pierced with loop-holes for musketry. Small areas enclosed by parapets of earth are also so called.
Tamp. To close up the entrance to the chamber of a mine, so that the explosion may not find vent through the gallery.
Tenaille. A low work in the main ditch of a fortress.
Terreplein. The interior area of a work; also the upper surface of a rampart.
Tête-de-pont. Any work constructed on the bank of a river with its rear bounded by the stream in order to defend the approaches to a bridge.
Tower-bastion. A tower of stone or brick in the form and situation of a small bastion.
Traverse. Any mass of earth across the interior of a work for protection against enfilade or ricochet fire.
Trenches. The excavations made in a siege for cover against the fire of the fortress.
Trous-de-loup. Holes or pitfalls with stakes planted at the bottom, to obstruct the advance of an assailant.

Zig-zags, or *Approaches*. The trenches by which the besiegers advance, in oblique directions, towards the works of the fortress.

FORTIFICATION



FORTIFICATION

Attack & Defence of Fortresses

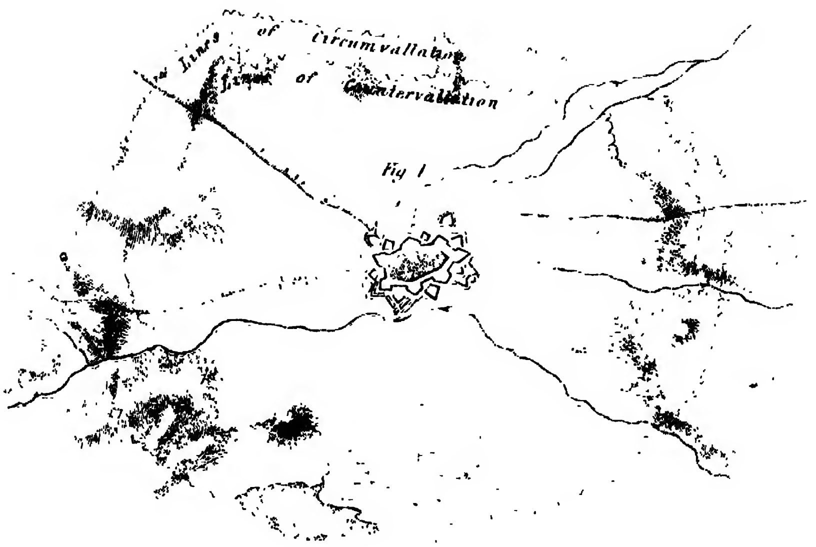


Fig 1

Fig 2

Fig 3

Fig 4

100 200 300 400 500 Yards

FORTIFICATION

Military Mining.

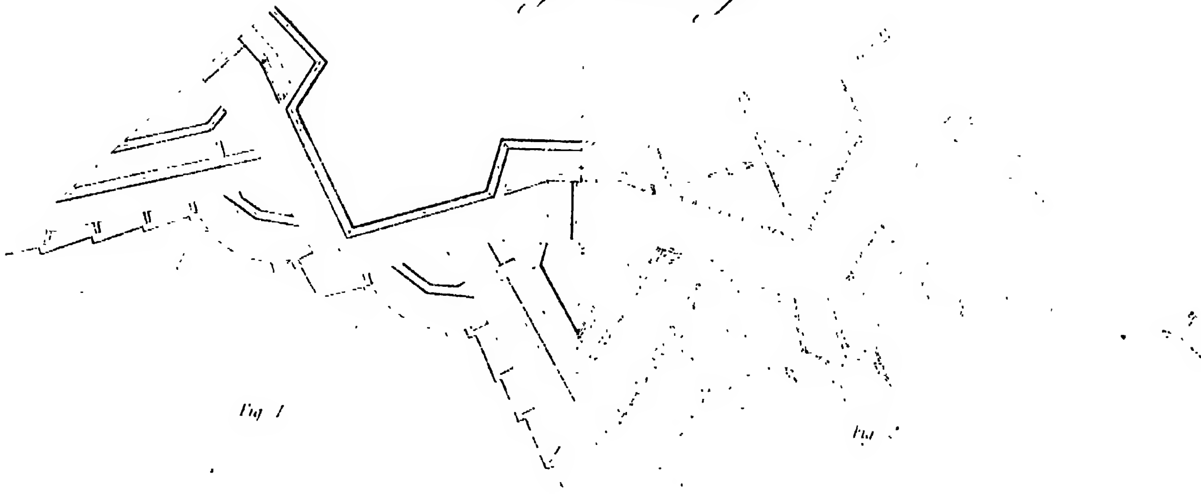
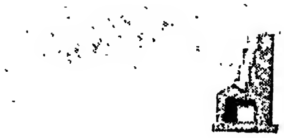


Fig 1

Fig 2



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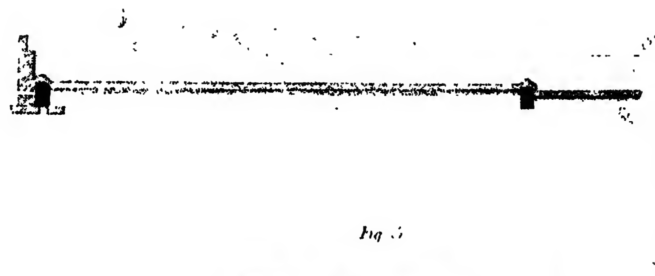

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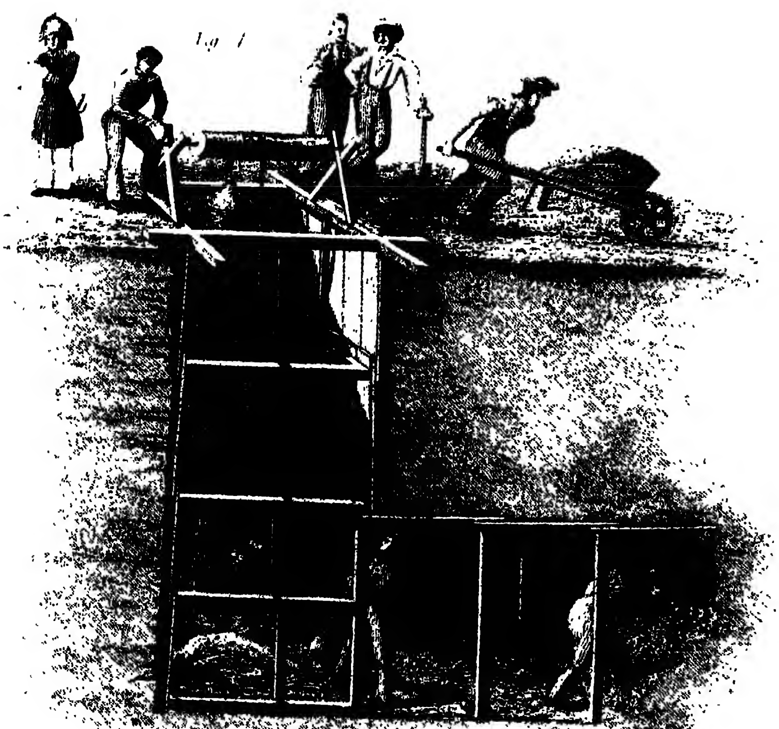
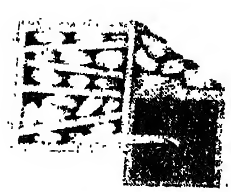


Fig 5

Fig 6



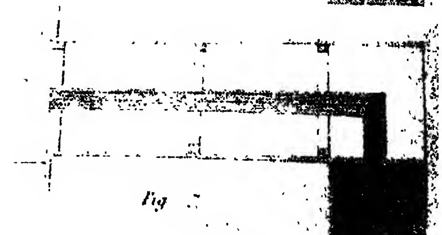
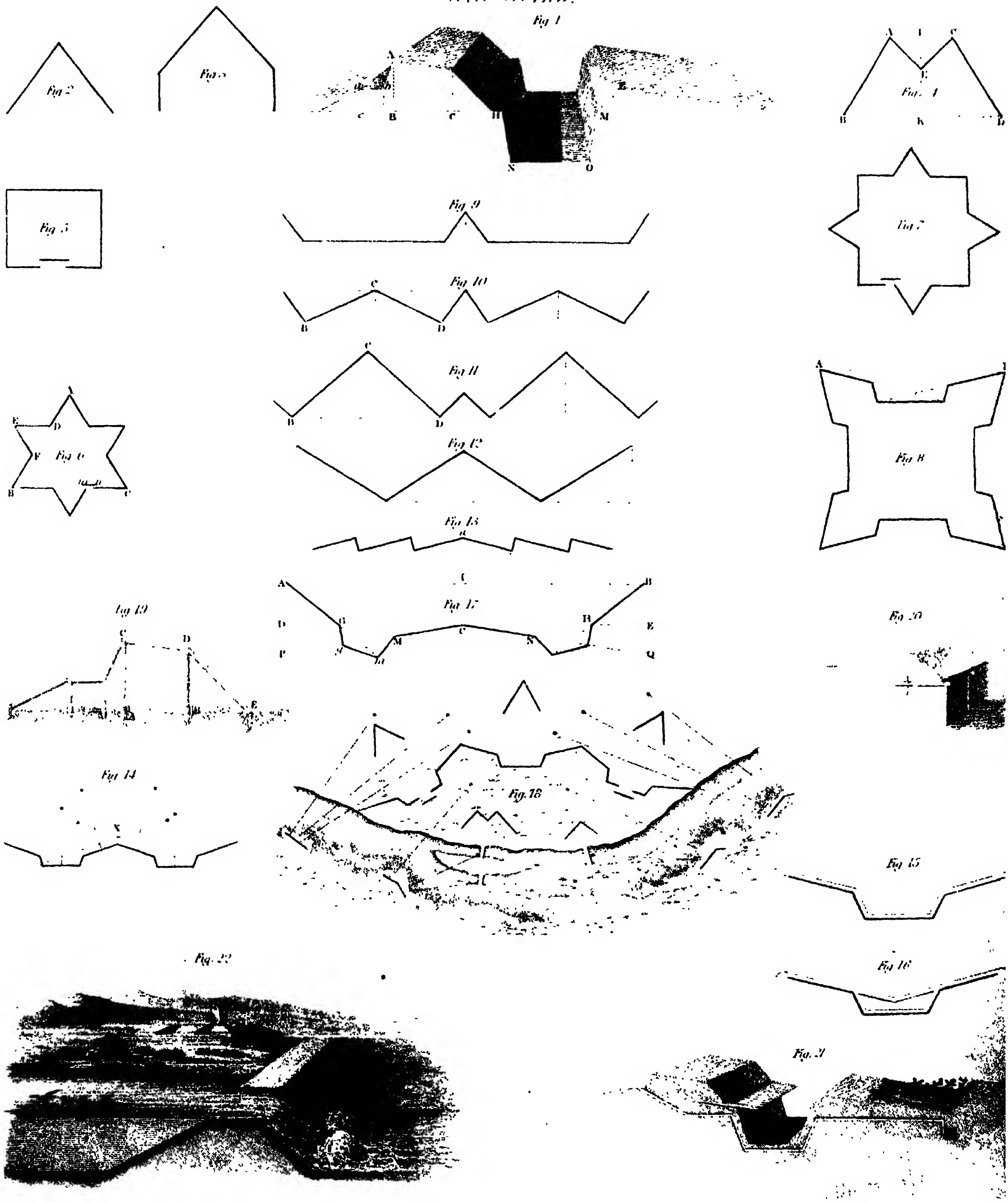


Fig 7

FORTIFICATION

Field Works.



Naval Architecture.

Introductory remarks.

(1.) It is impossible to contemplate the Naval power of England, and not to feel a deep interest in its history and growth. Such an inquiry cannot but command our attention, mingled up as it is with the elements of our political power, and forming the foundation of all that influence which the name of Britain has for so long a period maintained in the World. The limits of an Essay, like that upon which we are about to enter, will not, however, permit us to do more than glance at a subject connected with so many splendid names, and so many transcendent events,—with victory and conquest in their largest sense,—with civilization and the whole train of the useful Arts,—with all that can impart an interest to a Nation like our own, and to the wide and extended empire of Man.

Division of our Naval history.

(2.) It has been usual to divide our Naval History into three periods: the first embracing all that preceded the reign of Henry VIII.; the second ending with the Restoration of Charles II.; and the last descending from the time of the Restoration to the present day.

Henry VII.

(3.) The first ship actually belonging to the Royal Navy was the Great Harry, built by Henry VII. in the third year of his reign, at an expense of £14,000; this Monarch being the first who thought of raising a Naval force sufficient for the service of the State. Prior to this our Kings had neither arsenals nor dock-yards; and by the Report of the Commissioners for Revising and Digesting the Civil Affairs of the Navy, (1805,) it appears, that the permanent Naval force of our Monarchs consisted only of fifty-seven vessels, each carrying twenty-one men and a boy, as well armed and fitted for war as the circumstances of the times would permit. The Cinque Ports were bound by their Charters to furnish these vessels annually, free of expense, for fifteen days, after receiving forty days' notice from the Crown. Whenever a greater force was required, ships were hired from the merchants at home, or from those of Dantzic, Hamburg, Lubec, Genoa, and other ports.

No Dock-yards.

Henry VIII. Admiralty and Navy Board formed.

(4.) The Naval power of England began to assume a regular and systematic form during the reign of Henry VIII. That Monarch formed an Admiralty and Navy Board, founded the Trinity House, and established the Dock-yards at Deptford, Woolwich,* and Portsmouth.† He drew up a code of regulations for the Civil government of the Navy, which has formed the basis of all the instructions from time to time issued respecting it. Henry appointed several great officers for carrying into execution his Naval plans; *viz.* a Vice-Admiral of England, a Master of the Ordnance, a Surveyor of the Marine Causes, a Treasurer, Comptroller and General Surveyor of the Victualling department, a Clerk of the Ships and Clerk of the Stores. These officers were commanded to meet once a week at an Office on Tower Hill, to consult together for the good order of the Navy, and to report their proceedings monthly to the Lord High Admiral. Notwithstanding, however, this approach to a regularly organized system in Naval affairs, the ships belonging to the Crown formed only a part of the Naval force employed in time of war. The tonnage at this time, according to Mr. Derrick's *Memoirs of the Navy*, amounted to 12,455 tons, and the mariners and soldiers to 7730.

Edward VI. Encouragement given by him.

(5.) During the reign of Edward VI. encouragement was given to the increase of seamen by preventing the trade from being carried on in foreign bottoms. The fleet at this time was divided into a Summer Guard and Winter Guard, the former consisting of 2540 tons and 1730 men, and the latter of 2150 tons and 1516 men. The tonnage at the death of this Monarch amounted to 11,065 tons.

Mary. Diminution of Navy.

(6.) During the reign of Mary, the fleet diminished exceedingly. At her death the tonnage amounted only to 7110 tons, and the ships and vessels to twenty-six.

Elizabeth. Encourages the Navy.

(7.) Elizabeth attended to the Navy with peculiar care. She ordered a rigid inquiry to be made into its condition and the causes of its late decay. She commanded timber to be preserved for ship-building, caused her magazines to be filled with stores, and ordered many pieces of brass and iron cannon to be cast. She encouraged her merchants to build larger vessels for the purpose of being converted into ships of war, when necessary; and what is singular, her Commissioners had the power of rating them 50 or 100 tons more than their actual admeasurement. To stimulate her own ship-builders, she went to Woolwich to the launching of a new ship, and called her by her own name. She augmented also the pay of her Naval officers, raised the wages of her seamen, and invited to her dominions foreigners who were skilled in the Art of Navigation. She encouraged, also, the younger branches of her Nobility to enter the Navy, and settled a part of her revenue, amounting to £9000 a year, towards its ordinary supply. Sir Francis Drake and Sir John Hawkins, two renowned Commanders, advised the establishment of a Chest at Chatham for the relief of seamen wounded in their Country's service. The proud titles of Restorer of the Naval power and Sovereign of the Northern Seas, were hence justly bestowed upon Elizabeth. At the time of her death, the Royal Navy consisted of forty-two ships of 17,055 tons burthen, and manned by 8346 seamen. The fleet by which the Spanish Armada was defeated, consisted of 176 ships carrying 14,992 men; but of these only thirty-four ships with 6225 men belonged to the Crown. In the last twenty-five years of the reign of Elizabeth, the Royal Navy was almost doubled. The annual expense amounted to £30,000.

Her personal exertions.

Encourages her Nobility to enter the Navy.

James I.

(8.) James I. was not negligent of the Navy, in the former part of his reign, expending £50,000 annually on it, exclusive of timber amounting to £36,000, yearly obtained from the Royal forests. According to Sir Walter Raleigh, it was the practice at this time to build ships by contract. In 1609 Commissions were appointed to rectify many abuses which had insensibly crept into the Navy. In 1610 the Prince was built, of 64 guns and 1400 tons burthen, being the largest ship

Large ship constructed.

* Woolwich is called the Mother Dock by Camden.

† In 1650, there was no mast house or dry dock, nor above 100 shipwrights in this Dock-yard. The first dry dock was formed in 1655.

Naval Architecture.

hitherto constructed in England. "This Royal ship was double built, and most sumptuously adorned within and without, with all manner of curious carving, painting, and rich gilding, being in all respects the greatest and goodliest ship that ever was built in England; and this glorious ship the King gave unto his son Henry Prince of Wales.* The great workmaster in building this ship was Mr. Phineas Pett, sometime Master of Arts of Emanuel College in Cambridge."† In 1619, we find a reference made to the Wardens and Assistants of the Shipwrights' Company, respecting the survey of ships at Deptford; and in the Naval Minutes of Mr. Pepys it is observed, that "the Shipwrights' Hall did anciently view and approve of the draught of the ships that were to be built for the King, and to survey them in the building."‡ In 1620 the King in his Speech to the Parliament affirmed, that £20,000 a year had been saved in the Naval department; and in 1623 the ordinary expenses of the fleet were reduced from about £54,000 a year to £30,000. At the death of King James, the Navy consisted of thirty-three ships, measuring 19,400 tons, proving that an augmentation of the dimensions of ships had taken place.

Shipwrights' Company.

Improvements.

(9.) Sir Walter Raleigh in his Discourse on the invention of shipping, and on the improvements that had been made therein in the reigns of Elizabeth and James, remarks, that "in my own time the shape of our English ships hath been greatly bettered. It is not long since," he continues, "the striking of the topmast hath been devised. Together with the chain-pump, we have lately added the bonnet and drabler. (Sails.) To the courses we have devised studding sails, sprit sails, and top sails. The weighing of anchors by the capstan is also new. We have fallen into consideration of the length of cables,§ and by it we resist the malice of the greatest winds that can blow. We have, also, raised our second decks." These different inventions seem to mark an era of active mechanical improvement.

Charles I. Sovereign of the Seas built.

(10.) Thirteen years after Charles I. ascended the throne, a fleet of sixty sail was equipped. Before the Civil War broke out, the King built at Woolwich a ship called the Sovereign of the Seas. Of this "famous vessel," it was said that "she measured 128 feet or thereabouts, by the keel, her main breadth 48 feet, and in height, from the bottom of the keel to the top of her lantern, 76 feet." It is mentioned of her, as a circumstance worthy of note, that "she bore five lanterns, the biggest of which would hold ten persons upright." That she had also "three flush decks, a forecastle, half-deck, quarterdeck, and roundhouse. Her lower decks had thirty ports for cannon and demi-cannon; middle tier thirty for culverines and demi-cannon; third tier twenty-six for other ordnance, forecastle twelve, and two halfdecks have thirteen or fourteen ports, more within board, for murdering pieces, besides ten pieces of chase ordnance forward, and ten right aft, and many loopholes in the cabins for musket-shot. She hath two galleries besides, and all of most curious carved work, and all the sides of the ship carved with trophies of artillery and types of honour, as well belonging to sea as land, with symbols appertaining to Navigation; also their two Sacred Majesties' badges of honour; arms with several angels holding their letters in compartments, all which works are gilded over, and no other colour but gold and black. Upon the stern-head a Cupid, or child bridling a lion; upon the bulk-head, right forward, stand six statues in sundry postures; these figures represent Concilium, Cura, Conamen, Vis, Virtus, Victoria. Upon the hawsers of the water are four figures, Jupiter, Mars, Neptune, Eolus; on the stern Victory in the midst of a frontispiece; upon the beak-head sitteth King Edgar on horseback, trampling on seven Kings."*

This ship occasioned complaints against Ship-money.

(11.) To this vessel, the largest that ever had been built in England, and said to have been designed only for splendour and magnificence, some have attributed those loud complaints against Ship-money, which marked this Monarch's eventful reign. By building the Sovereign of the Seas it is, however, admitted that Charles rendered a great service to the Navy, by setting the example of increased dimensions, to which all the successes of the English over the Dutch in 1653 were ascribed. In the year 1633 the Navy consisted of fifty ships,† measuring 23,695 tons, carrying 1430 guns, and manned by 9470 men. On the breaking out of the Rebellion in 1641, the number was reduced to forty-two ships, with a burthen of 22,411 tons. Prince Rupert quitted the Kingdom in 1648 with twenty-five ships, none of which ever returned. It has been said that Cromwell could command at the beginning of his usurpation only fourteen ships of war, some of which carried but 40 guns. The first frigate was built in 1649, by Mr. Peter Pett, for a privateer for the Earl of Warwick. Mr. Pett adopted the idea from a French frigate he had seen in the Thames.‡

State of Royal Navy.

Commonwealth. Exertions of Cromwell.

(12.) The vigorous exertions of Cromwell raised the Navy, however, in six years, to 157 ships, carrying 4390 guns and 21,910 seamen, exclusive of the guns and men for four ships then building. Of these, forty-six were foreign built, mostly captured in the Dutch

* It is mentioned as a remarkable circumstance, that the Prince went at three o'clock in the morning to her launching, and named it after his own dignity.

† A circumstance worthy of notice here is, that Mr. Pett, in 1613, remarked, that he "began to victual all the shipwrights and workmen employed."

‡ Mr. Pett was elected and sworn Master of the Shipwrights' Company in April 1606, on which occasion, he says, they kept a feast with a great number of their friends, at the King's Head, in New Fish-Street; and by the new Charter, granted in 1612 for incorporating the Shipwrights of England, he was also ordained the first Master.

§ The cables before this time are said to have been only 78 fathoms long; at the present time they are 101 fathoms long.

* "On the 14th of May, 1635," says Mr. Pett, "I was commanded by His Majesty to hasten into the North, to provide and prepare the frame-timber, plank, and tree-nails for the great new ship at Woolwich. I left my sons to see the moulds and other necessaries shipped in a Newcastleman, hired on purpose to transport our provisions and workmen to Newcastle. The frame, as it was got ready, was shipped and sent in Colliers from Newcastle and Sunderland. The 21st December, 1635 we laid the keel in the dock. She was launched 13th October, 1637, and named the Sovereign of the Seas."

Engravings were made of this ship by Payne, on two plates, joined, 3 feet long, and 2 feet 2 inches high. The original picture is said to have been painted by Vandevelde.

In the list of the King's ships for 1633, the armament of the Prince Royal is distinguished by an *odd* number, namely 55 guns.

† At the present moment, exactly two hundred years after the date specified above, in a time of profound Peace, and when no thought of reductions have been made, the Navy consists of 574 ships.

‡ It would appear from Mr. Pett's monument, in St. Nicholas Church, Deptford, that he was the *inventor* of frigates; this, however, was not the case.

War. During the reign of Charles I. the length of the keel began to be regarded as an element proper to be entered in the official lists; but at the period now under review, the breadth and depth also were inserted. In the list for 1652 we find a 100-gun ship first mentioned, and, singularly enough, called the Sovereign. The length of her keel was 127 feet, breadth 46 feet 6 inches, depth 19 feet 4 inches, and tonnage 1141 tons.*

(13.) Cromwell was so sensible of the respect paid by foreign States to the Naval power of this Country, that, instead of reducing his Navy at the conclusion of the War in 1654, he ordered all the ships to be repaired and put into good condition; he also ordered new ones to be built, and the storehouses and magazines to be replenished as in a time of the greatest danger. Sixty ships were either built or building between 1646 and 1653; and the pay of the sailors was raised from 19*s.* to 24*s.* a month. Estimates for the maintenance and support of the Navy were for the first time laid before Parliament, and the Protector obtained an annual grant of £400,000 for that purpose. During the short and feeble Administration of Cromwell's son, the Navy, it is probable, somewhat declined, the funds being diverted to various other purposes.

Charles II.

(14.) There seems some diversity of opinion respecting the actual amount of the Navy at the time of the Restoration. According to some authorities the whole fleet consisted but of sixty-five ships and vessels of all sizes. Mr. Derrick, however, is inclined to believe the actual amount to have been 162 ships and vessels, with a tonnage (as stated in *Columna Rostrata*, p. 251) of 62,594 tons. In the second Dutch War in February, 1665, it is known the English fleet at sea, and ready for sea, consisted of 114 sail, besides fire-ships and ketches.

Ability of Charles for Naval affairs.

(15.) According to Mr. Pepys, King Charles II. "possessed a transcendent mystery in all maritime affairs." For the first ten years of his reign he was undoubtedly very intent on augmenting our Naval power. He nominated the Duke of York Lord High Admiral; and, by the advice of Mr. Pepys, a Committee was appointed, over which the Duke presided, Mr. Pepys acting as Secretary. The powers formerly granted to the Admiralty and Navy Board were recalled, the Lord High Admiral undertaking the supreme management, with the aid of three new Commissioners, the Comptroller, the Surveyor, and the Clerk of the Acts. Seventy-six ships of the line, stored for six months, were called into active sea pay, besides merchantmen, and a numerous train of ketches, smacks, yachts, &c., with more than 12,000 seamen. At this time, also, there were thirty new ships building, and an abundance of Naval stores.

Construction of two-deck ships.

(16.) In 1663 and 1664 a stimulus was given to our ship-builders by the Dutch and French having built ships of two decks, carrying from 60 to 70 guns, capable of stowing four months' provisions, and having their lower guns four feet above the water. The English frigates at this time were what was then called "Dunkirk built," narrow and sharp vessels, and hence incapable of carrying their guns little more than three feet above the water, and only ten weeks' provisions. Sir Anthony Deane, a keen observer of Naval affairs, and the most accomplished ship-builder at that time in England, endeavoured to correct these defects, by causing two ships to be built capable of carrying six months' provisions, and having their guns 4½ feet above the water.

Charge for the Navy.

(17.) From 1660* to 1670 the charge of the Navy, according to the Lord Keeper Bridgman, had never amounted to less than £500,000 a year. It is remarkable, however, that, in 1665, Lord Clarendon told the Parliament that the Naval and Military stores were entirely exhausted. This is one among many instances of the conflicting testimonies met with in the Public Accounts of the Country, of which our own day is not without examples.

Extravagance of Charles.

(18.) In 1673 the Duke resigned his high office, and from that time until May 1679, the affairs of the Admiralty were managed by the King himself. The vicious habits of this Monarch wasted in dissipation those sums which ought to have been employed in maintaining the Navy; and so sensible was the Parliament of this, that £300,000 was not voted for the Naval service in 1675, without making particular restrictions respecting the appropriation of the money. In 1677, also, £586,000, voted for the building of thirty ships, was subjected to like injunctions. From 1672 to 1684, the affairs of the Navy were managed by a Commission, but so badly were they conducted, that the Naval force at sea had declined to twenty-two ships, none of which were larger than a fourth-rate; whilst the vessels in harbour were totally unfit for service, and falling rapidly into decay. Several of the ships had been reported by the Navy Board to be in danger of sinking at their moorings. The magazines of stores were also reduced to less than £5000 value. Sir Anthony Deane, one of the Commissioners of the Navy, resigned in 1680 or 1681, foreseeing the condition to which the Navy would be reduced. In 1684 the Duke resumed the management of Naval affairs, assisted by the able advice of Mr. Pepys, but the ships continued to decline till the King's decease.

Navy managed by a Commission.

James II.

(19.) It is remarkable, however, and the circumstance ought to operate as a salutary caution in every after Age, that the power and energy of the Duke could not arrest this declension; nor for a whole year after he had become King, could he, with the whole weight of his new authority, check the progressive decay. He resolved therefore to suspend all the ordinary modes by which the business of the Navy had been conducted by the Navy Board, and to call into his aid other persons, on whose experience and industry he could rely. These he joined to a select number of the old Commissioners, in effecting his work of reformation. A part of these members, six in number, was required to sit constantly at the Board, and among them was the able and conscientious Sir Anthony Deane. Three members of the Board superintended the Dock-yards at Chatham, Portsmouth, and Woolwich, and the remainder, with the aid of Lord Falkland, were occupied in adjusting the accounts. Of these Commissioners, Mr. Pepys has remarked, "That they were men possessing a practised knowledge of every part of the works and methods of the Navy, both at the Board and in the Yards; a general mastery in the business of accounts, vigour of mind, and improved industry and integrity;" qualities, we would add, which, in every Age, cannot but be of the first importance to the public service.

* In the list of the Navy for 1651, the armament of the Revolution was distinguished by an *odd* number, *viz.* 85 guns.

* In 1660 the Dutch gave his Majesty a yacht called the Mary. This is the earliest time at which the name Yacht is to be found in our Naval records.

Inquiry into decay of the Navy.

(20.) The first inquiry of the new Commissioners was into the rapid decay of the thirty ships voted to be built in 1677. Some of these vessels were completed the following year, but others not until 1682; and it appeared that their decay did not result so much from the haste with which they had been built, as from the omission of the necessary and ordinary precautions for preserving them. The labours of the Commissioners were so entirely satisfactory, that on the close of the Commission on the 12th of October, 1688, there remained only three ships to be examined of the whole number originally proposed to be repaired. Added to this, stores for eight months instead of six were left in the magazines, disposed in the most admirable order, and ready to be applied to the proper ships.

Arrangements of stores.

The value of the stores so laid apart for each particular ship, together with those on board the ships at sea, amounted to above £280,000. The Commissioners also left in store a further reserve of wood, hemp, pitch, tar, rosin, canvass, iron, and oil, of above £100,000 value; and more new magazines were created in the course of this time than had ever existed before.

Improved condition of the Navy.

Thus the Navy was raised from its feeble and abject state, to a degree of prosperity unparalleled in any previous period of its history. Among other prudent regulations, the Commissioners abolished the irregular supplies of stores which the boatswains and carpenters of ships had hitherto controlled, and fixed one uniform establishment of sea-stores for a ship of each rate. On the abdication of King James, the Royal Navy consisted of 173 ships, having a burthen of 101,892 tons, mounting 6930 guns, and carrying 42,003 men.

William and Mary.

(21.) The Revolution of 1688, which happily accomplished so many important changes, left the code of Naval regulations established by the Commissioners in the preceding reign unaltered. The actors in that important scene wisely left untouched a system which had produced so many important results.

Several large ships built.

Accordingly, an Act was passed in the second year of the reign of William and Mary, for building seventeen ships of 1100 tons each, and carrying 80 guns; three of 1050 tons, and carrying 70 guns each; and ten of 900 tons each, carrying 60 guns, making thirty ships in the whole. The first-mentioned ships had three decks, which mode of construction continued till the War of 1756.

Dock-yards.

In the following year money was voted for a Dock-yard at Plymouth, and also for building additional dry and wet docks at Portsmouth. In 1693, with a view of creating an abundant stock of Naval stores, the sum of £1,926,516 was granted to their Majesties, together with £23,106 for finishing the Naval yard at Plymouth, also £10,908 for building four bomb-vessels, and £68,400 for constructing eight 40-gun ships.

Infernal machines.

About this time, vessels called Machines or Infernals were first employed as fire-ships; their inventor is said to have been M. Meesters. Advice-boats, so called officially, are said to have been employed for the first time in 1692, before the Battle of La Hogue, in order to gain intelligence of what was taking place at Brest.

(22.) At the accession of King William, the Royal Navy consisted of 173 ships, admeasuring 101,892 tons; and at his death it had augmented to 272 ships, with a tonnage of 159,020 tons, the increase being more than one-half, both as to the number and the tonnage of ships.

Anne.

(23.) In the early part of the reign of Queen Anne, the Country was visited by a most desolating storm.* The Navy suffered a great loss, and the House of Commons with the greatest promptitude addressed her Majesty, desiring her to give immediate directions for repairing it, and for building such "capital" ships as she thought fit.

Desolating storm.

Orders were accordingly given to that effect; but it is somewhat remarkable, observes Mr. Derrick, that no money was directly voted by the House in this reign for the building of ships, though in November 1705 a sum was granted for ordnance stores, and carriages for eight new ships, built in lieu of part of those lost in the great storm.

Navy very popular.

The Navy at this time was exceedingly popular, and the many disasters it met with served as a plausible ground for augmenting it. The seamen of the Royal Navy were particularly encouraged, the utmost care being taken of the sick and wounded, and prize-money being speedily paid: regulations which came home to the generous hearts of the sailors, and inspired them with new ardour in their Country's cause. The earnestness of the House of Lords in favour of the well-being of the Navy may be gathered from the following extract of an Address of that body in March 1707:

"*It is a most undoubted maxim, that the honour, security, and wealth of this Kingdom does depend upon the protection and encouragement of Trade, and the improving and right managing its Naval strength. Other nations, who were formerly great and powerful at sea, have, by negligence and mismanagement, lost their Trade, and have seen their maritime power entirely ruined. Therefore we do in the most earnest manner beseech your Majesty, that the sea affairs may always be your first and most peculiar care.*"

At the time of the Queen's death, in 1714, the Royal Navy consisted of 247 ships, bearing 167,219 tons.

George I. Survey of stores.

(24.) In 1715, the year following the accession of George I., a general survey was made of all the stores in the different Dock-yards, which were distributed as follows:

At Deptford	£90,514
Woolwich............	60,174
Chatham............	186,855
Sheerness............	35,216
Portsmouth	182,076
Plymouth............	109,833
Total ...	£664,728

From 1715 to 1721 inclusive, the sum of £1,052,395 was voted for extraordinary repairs and the rebuilding of ships. From 31st of March, 1713, to 31st of December, 1721, there were either built or rebuilt thirty-four ships of the line, three of which carried 100 guns, and twenty-five ships of 40 guns and under. In 1719 new dimensions were established for several classes of ships. The Navy on the whole declined in this reign in a small

* This storm was the most tremendous ever known in the History of the World. It began about the middle of November, and did not reach its greatest height until the morning of the 27th. The Eddystone Lighthouse was blown down at this time. A General Fast was appointed in consequence of the storm. The Queen issued a Proclamation, ordering that all the widows and families of such officers and seamen as had perished by the storm in her Majesty's service, should be entitled to her bounty in the same manner as if they had been actually killed in battle. De Foe, the author of *Robinson Crusoe*, was suffering in Newgate at this time, and composed the *Storm*, being a collection of the most remarkable casualties which happened in this great tempest.

Naval Architecture.

degree, and at the death of the King consisted of the following ships:

Rates or Classes.	Guns.	Number.	Burthen in Tons.
1st	100	7	12,945
2d	90	13	20,125
3d	80	16	21,122
„	70	24	26,836
4th	60	18	16,925
„	50	46	33,829
Ships of the line		124	131,782
Of 40 guns and under		109	39,080
		233	170,862

Notwithstanding the decrease of number, there is still an increase of tonnage, showing that a gradual augmentation of magnitude was insensibly taking place.

George II.

(25.) George II. ascended the throne in 1728, and on the 31st of July of that year, another general survey of stores was made in the several Dock-yards, and the total amount found to be £636,756. For the last six years of the preceding reign, no money was voted for the building and repairs of ships, and the same omission took place during the first and second years of this reign. A ten years' Peace had seemed to render any grant unnecessary.

General survey of stores.

Alteration of ships' guns.

(26.) In 1743, the establishment of ships' guns was altered by order of the King and Council;* and in the succeeding year all prizes taken by his Majesty's ships were declared by the King's Proclamation to be the property of the captors for the time to come.

(27.) In 1744 or 1745, general complaints were made that our ships were not built of sufficient strength, nor their guns carried sufficiently high above the water. They were also said to be very crank, and their weight of metal inferior to those of the enemy, whose batteries were said to be "always open." The Lords Commissioners of the Admiralty, therefore, gave directions to the flag officers, the Surveyor of the Navy, and the master shipwrights of the Dock-yards to prepare a scheme of dimensions and scantlings, and also a draught for a ship of each class; and from these draughts and plans the elements then judged to be most correct were deduced. The

Scheme of dimensions and scantlings.

ships built according to this establishment were found to carry their guns well, and acquired the name of stiff ships; but they were said to be "fully formed" in their after-part. In the War of 1756 some further improvements in the draughts were made, and also a further augmentation of dimensions. The following Table will show the progressive additions made to the Navy during this reign:*

Date.	Ships of the line.	Ships of 40 guns and upwards.	Total.
December 1st, 1730. .	124	114	238
January 1st, 1739 . . .	124	104	228
June 25th, 1742.	125	146	271
December 31st, 1744 .	128	174	302
May 26th, 1748.	140	199	339
January 1st, 1750 . . .	126	156	282
January 1st, 1756 . . .	142	178	320

George III.

(28.) The reign of George III. was destined to see our Naval power rise to unparalleled splendour. At the accession of that upright and conscientious Monarch, on the 25th of October, 1760, the Royal Navy consisted of 127 sail of the line having a burthen of 182,829 tons, and 285 ships of 50 guns and upwards, with a tonnage of 138,275 tons. In the War of 1762 twenty-six sail of the line and eighty-two smaller ships and vessels were built in the merchants yards. Twenty-four sail of the line and twelve smaller ships also were launched in the King's yards between the declaration of War in 1756 and the proclamation of Peace in 1763. According to Beatson, forty-two sail of the line, French and Spanish, together with sixty-nine vessels of 50 guns and under, were either taken or destroyed by the English during that War. Of these, twenty-one sail of the line were added to our Navy.

State of the Navy.

(29.) During this War a resolution was wisely adopted

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* In the proposition of the Lords Commissioners of the Admiralty for the foregoing establishment, they mention that "since the year 1733, but especially since 1st January, 1740, the dimensions of ships of your Majesty's Navy have been much increased. We do therefore humbly propose that the number and nature of guns directed by your Majesty's Order in Council of 31st January, 1733, may be established on such ships of your Royal Navy as have been ordered to be built or rebuilt since 1st January, 1740, or shall be hereafter built or rebuilt, with this exception, that whereas the ships of 50 guns are now built of such large dimensions that they can conveniently carry 22 guns of 24-pounders upon the lower deck, and as many of 12-pounders upon the upper deck, with 4 guns of 6-pounders upon the quarterdeck, and 2 guns of 6-pounders upon the forecastle, the same may be established upon them, instead of those proposed in the year 1733."

By the draughts established for building ships in 1745, those of 64 and 58 guns had port-holes for 70 and 60 guns as follows:

	64 to carry 70.	58 to carry 60.
Lower deck..........	26	24
Upper deck	28	26
Quarterdeck	12	8
Forecastle	4	2
	70	60

These establishments of guns, and the various changes which they have undergone in different periods of our Naval History, are well worthy of the attention of him who aims at a general and comprehensive view of this important subject.

* A Naval uniform was first established in 1748 by George II., and, according to Mr. Locker, resulted from a Club of sea officers, who met every Sunday evening at Will's Coffee-house in Scotland Yard, for the purpose of watching over their rights and privileges; and who determined among other matters, "that a uniform dress was useful and necessary for the commissioned officers, agreeable to the practice of other nations. A Committee was hence appointed to wait upon the Duke of Bedford and the Admiralty, and ask, if their Lordships approve, that they will be pleased to introduce it to his Majesty."

When it was determined to establish the uniform, Mr. Forbes, then Admiral of the Fleet, was summoned to attend the Duke of Bedford, and being introduced into an apartment surrounded with various dresses, his opinion was asked as to the most appropriate. The Admiral said, red and blue, or blue and red, as these are our national colours. "No," replied his Grace; "the King has determined otherwise. For having seen *my* Duchess riding in the Park a few days ago, in a habit of blue faced with white, the dress took the fancy of his Majesty, who has appointed it for the uniform of the Royal Navy."

Before 1748, Mr. Locker remarks, "every man dressed as seemed good in his own eyes. Some of the crack Captains carried it so far as to have a special uniform for their own ships. My late gallant father, who went to sea in 1746, used to tell us, that Captain Windham, and all the officers of the Kent of 70 guns, in which he embarked, wore grey and silver, faced with scarlet! Such foppery, however, at that period, was not unfrequently combined with check shirts and petticoat trowsers."

"In the Hall at Greenwich may be seen," continues Mr. Locker, "every variety of cut and complexion of dress. Nottingham, Raleigh, and Torrington expand their dignities in courtly costume Lawson, Harman, and Monk frown in buff belts and jerkins. Sandwich, Munden, and Benbow shine forth in armour; while Rooke, and Russell, and Shovell, the heroes of a softer Age, are clothed in crimson and Lincoln green, surmounted with the flowing wig, which then distinguished alike the men of the robe and of the sword."

New scale of ships.

of not building any more 80-gun ships with three decks, or any 70 or 60-gun ships. Ships of 74 and 64 guns on two decks were built instead of those of 80 guns, and 50-gun ships with a roundhouse, for the accommodation of flag officers in time of Peace, instead of ships of 60 guns. The first 74 and 64-gun ships that were built proved too small for their weight of metal, but those constructed towards the latter part of the War were of larger dimensions. In 1766 very great improvements were made in Plymouth and Portsmouth Dock-yards.

(30.) In the armament which took place in 1770, in consequence of the dispute with Spain respecting the Falkland Islands, a large proportion of the ships ordered to be fitted for sea were found very defective; and had a War of long continuance taken place, the most serious consequences might have ensued. An insufficient number of shipwrights in the Dock-yards, together with an improper limitation of their working hours, seemed to have been the cause.

(31.) At the commencement of the American War in 1775, we had 131 ships of the line and 209 vessels of 50 guns and under. The Navy was augmented with every possible rapidity, particularly with frigates, sloops, and other small vessels.

Zealous efforts of the Court of Directors.

(32.) In 1779, the Court of Directors of the East India Company passed a resolution to present three ships of 74 guns to the Crown.* The Naval force continued to receive very rapid augmentations, as well by captures from the enemy as by building. No exertions, indeed, it has been remarked, could possibly be deemed extravagant, when the activity of our enemies was considered.† The supplies voted by Parliament very far exceeded those of any former period. At the signing of the Preliminaries of Peace in 1783, there were 174 ships of the line, and vessels of 56 guns and under amounting to 443, the total tonnage being 500,781 tons. Thus it appears, that the Navy at this period exceeded what it was at the end of the War in 1762 by thirty-three sail of the line, having a tonnage of 71,070 tons, and of other vessels by 152, with a tonnage of 86,405; making a total increase of 185 ships, and a total augmentation of tonnage amounting to 157,475 tons. The French, Spanish, and Dutch ships taken or destroyed by the English in the course of this War amounted to twenty-six sail of the line, and sixty-one vessels of 54 guns and under, besides sloops and vessels of other kinds.

Great power of Navy at this time.

Dimensions of ships increased.

(33.) During this War, almost every class of ships of 44 guns and under was considerably increased in dimensions, when any new ones were ordered to be built; and at the latter end of 1778, the greatest part of the second-rates were established with eight additional guns for their quarterdecks, thereby making them 98-gun ships.

Ships in ordinary.

(34.) In June 1783, several masters in the Navy were appointed to superintend the state of the ships in ordinary at Chatham, Sheerness, Portsmouth, and Plymouth. In the following year, the Navy Board wisely ordered that every individual ship built or put into good condition, should in future have a large proportion of the principal parts of her furniture and stores in readiness, and duly arranged in store for her, so that the remainder might not require more time to provide than the necessary period for her equipment would admit, however short that time might be. In addition to this important regulation, another originated with Lord Barham, of creating an establishment of stores of a great variety of kinds, as general magazines at each Dock-yard, and also at the other Naval stations, both at home and abroad. This arrangement resulted probably from the difficulties experienced in procuring some articles, and the high prices paid for others during the War; and the same, doubtless, must have been the case, in a greater or less degree, in most of the preceding Wars. Since that time the advantages of the plan have been abundantly proved. The following Table furnishes an account of the value of the principal articles in store at the several Dock-yards on the 31st of December, 1792

	Unappropriated.	Appropriated.	Total.
Deptford . .	£180,388	£38,170	£218,558
Woolwich .	164,406	25,144	189,550
Chatham . .	213,305	164,999	378,304
Sheerness .	50,699	21,108	71,807
Portsmouth	317,414	131,210	448,624
Plymouth .	326,880	179,259	506,139
Total .	£1,253,092	£559,890	£1,812,982

On January 1st, 1802, three months after the signing of the Preliminaries of Peace, the unappropriated stores remaining in the magazines at the several Dock-yards were as follows:

Deptford	£308,093
Woolwich.	600,656
Chatham	423,697
Sheerness.	99,400
Portsmouth	567,243
Plymouth	611,819
Total	£2,610,908

On comparing the value of the stores in the several Dock-yards at different periods, it will appear, that the magazines have been increased in a greater ratio than the ships, great as the increase in the latter has been. The confederacy among the Northern Powers, and the embargo in the Russian ports, in November 1800, would have been attended with the most serious consequences, had not the magazines been previously well stored. This instance alone proves the wisdom of the plan. Old ships were selected in this year, and afterwards fitted for the reception of ships' companies and stores, during the time ships were in dock refitting. Previously to this arrangment, serviceable ships, not in good condition, were made use of for the purpose, which did them considerable injury. These were denominated Receiving ships.

Task and job work.

(35.) Task work was introduced into the Dock-yards in 1775, and job work in 1784. The former of these

* We are no friends to the privateering system, regarding it as little better than a licensed system of plunder and fraud, but it would be improper to omit in an historical account like the present, a notice of the extraordinary exertions made by the traders of Liverpool at this period. According to Mr. Chalmers, (see his *Estimate of the Comparative Strength of Great Britain,*) that port alone fitted out, at the beginning of the War with France, between the 26th of July, 1778, and the 17th of April in the following year, 120 privateers, each armed with from 10 to 30 guns, but mostly with from 14 to 20. From an accurate list, containing the name and appointment of each vessel, it appears that these privateers measured 30 787 tons, carrying 1986 tons, and 8754 men.

† The War with Spain commenced in 1779, and with Holland in 1780. In August, 1779, the combined fleets of France and Spain, consisting of sixty-six sail of the line, besides frigates, &c. entered the Channel, and appeared off Plymouth. This formidable fleet was a proof of the immense activity of our enemies in augmenting their Naval force during the Peace, and particularly so when we consider their losses during the preceding War.

terms applies to new work, and the latter to repairs or old work. These plans were adopted in order to accelerate the work in the Dock-yards, and particularly with regard to the shipwrights. When task work was first introduced, notwithstanding the plan appeared very advantageous to the workmen, it was resisted by the shipwrights; and the reason assigned was that when any piece of timber proved defective or unfit for use, after having been fashioned to its intended shape, no compensation was provided for the workmanship performed. It was at length directed that the workmen should be paid a daily rate of wages for the time that might be lost in the conversion of unsound materials, and in the performance of some extra works; it was likewise ordered that they should have assistance in the heavy work of getting in the beams. Notwithstanding these concessions, the shipwrights persisted in their refusal to work by task until the year 1788, when it is said to have been adopted at their own solicitation. Equal reluctance was displayed by the men in adopting job work, but it was finally carried into effect in the same year as piece work. The first ship repaired by job in Plymouth yard was the Gibraltar of 80 guns.

Dispute respecting adoption.

Magazines.

(36) In 1787, it was directed that ships lying up in good condition should have the works of their magazines and store-rooms completed, in order to be the sooner ready for sea. In 1790, two ships of 110 guns each were ordered to be built, of the burthen of 2332 tons. These ships were to have 32-pounders on their main decks.

110-gun ships built.

(37.) To give an idea of the prodigious activity which prevailed in our Dock-yards, when the circumstances of the French Revolution compelled us to arm, it may be stated that on the 1st of December, 1792, there were only twelve line of battle ships in actual commission as fighting ships, but by the 1st of September, 1793, that number was augmented to seventy-two.* In like manner, at the former period, there were only thirty ships from 50 to 20 guns each in commission; but at the latter, this number was increased to 104. It was remarked, that no delay arose for want of stores, in consequence of the important measures adopted at the end of the War in 1783

Activity in our Dock-yards at the French [illegible]

(38.) In 1793, two very important improvements took place, *viz.* the lengthening of ships very considerably;† and the giving 44-gun frigates, and those down to 32 guns, four, instead of three-inch bottoms. The object of the first change was with a view of making them sail better; and of the second, to enable them to resist with greater effect any bearing on the ground. At this time, it is said, there was scarcely a class of ship or vessel whose plan of construction was not improved.

Lengthening of ships. Increasing thickness of their bottoms. General improvement of vessels of all kinds.

(39.) In 1794, the Caledonia of 120 guns, and 2602 tons burthen, was ordered to be built, and to carry 32-pounders on her main deck. This ship seems to have communicated an impulse to ship-building; she was built by Sir William Rule.

Ships of 120 guns built.

In 1797, seamen's wages were raised as follows:

Augmentation

	£.	s.	d.		£.	s.	d.	
Able from	1	4	0	to	1	9	6	per month
Ordinary	0	19	0	to	1	3	6	
Landsmen, (a new class)				..	1	2	6	

* Of these, two were of 110 guns, five of 100 guns, twenty-one of 98 and 90 guns. The total tonnage of ships of the line was 234,136 tons.

† The Prince, a 90-gun ship, was taken into dock at Portsmouth, and lengthened 17 feet.

The following Table will show the progressive increase of ships of the line, and of ships of 56 guns and under:

	Jan. 1. 1795.	Jan. 1. 1797.	Jan. 1. 1799.	Oct. 1. 1801.
Ships of the line........	145	161	176	180
Of 56 guns and under. .	454	530	627	684
Total.....	599	691	803	864

Thus the number of ships and vessels at the conclusion of the War in October 1801, exceeded the number at the close of the War in 1783 by 247 sail. On the 1st of August, 1799, the number of ships of the line in commission amounted to 154, which was the maximum at any part of the War. Of the ships belonging to the enemy, and taken or destroyed by the English in the course of the War, there were of the line and down to 54 guns inclusive, 86; of 50 guns 3; of frigates 206; and of sloops and small vessels 275; making a grand total of 570. The English ships taken or destroyed by the enemy, were of the line to 54 guns inclusive, 5; of 50 guns, 1; of frigates 12; and of sloops and small vessels 41; making a total of 59. The conquests of the English were therefore nearly as ten to one when compared with those of the enemy.

Great increase in the number of our ships.

Ships captured from the enemy.

(40.) In 1803, the Country was called on to renew a War which, if it had been tremendous before, was now calculated to unfold with redoubled horrors its awful and desolating effects. On the 15th of May, the Royal Navy consisted of 177 ships of the line, and of 56 guns and under 593, making a total of 770. On the 1st of January 1805, the total amount was 649; and on the 1st of October of the same year there were in commission of the line and to 54 guns inclusive, 121 sail; of frigates 158, and sloops, including hired armed ships and vessels, 416; making a grand total of 698. It was, indeed, a season of the most extraordinary activity, and the most remarkable energies were called into action. From 1808 to 1813 there were seldom less than from 100 to 106 sail of the line, from 130 to 160 frigates, upwards of 200 sloops, besides bombs, gun-brigs, cutters, schooners, &c. in active service. To this enormous service were to be added another 500 sail in ordinary, employed as prison, hospital, and receiving ships, all performing offices tending to make our Naval arm more powerful and efficient. Thus a thousand pendants floated proudly in the wind, the united burthen of the whole amounting to 800,000 or 900,000 tons. Our wide and extended commerce supplied an abundance of prime seamen, and the perpetual activity of our public and private yards served to keep every part of this gigantic machine in the most perfect order. A glorious succession of brilliant victories placed the Naval supremacy of the Country on the most transcendent height; and so well was this superiority maintained, that at the close of the most awful and sanguinary War which History had ever recorded, the accumulated Navies of the whole World bore but a small proportion to ours.

Renewal of the War 1803.

Amount of the Navy in 1803 and 1805.

Enormous fleets in actual commission.

Great number of ships otherwise employed in ordinary.

Brilliant results.

(41.) These great and transcendent exertions were aided by corresponding energies on shore. An entire renovation of the Civil departments of the Navy, and of the mechanical labour in the Dock-yards, served to infuse new life into a system, which, with even all its energies, had become impaired by corrupt systems of management. The period from 1803 marks, indeed, a new era in our existence as a Naval people. The Earl of St. Vincent, who had rendered so great services to his

Entire renovation of the Civil departments of the Navy.

Great services of the Earl of St. Vincent, in reforming the Civil departments of the Navy.

Country by the victory obtained near the Cape which gave to him his glorious title, not only had the merit of training up a body of first-rate seamen, and introducing the most effective modes of discipline at sea, but he also directed his keen and scrutinizing eye into the Dock-yards at home and abroad. It was evident to every Naval man, that there was an extravagant expenditure and an improper mode of conducting the public business in these great establishments; but it required a mind of a fearless cast and of great and comprehensive powers to grapple with its multiplied details. Such a man was Lord St. Vincent.* Commissioners were appointed to inquire into our great Naval establishments; and these able men† entered on their important task with a boldness and decision which at once removed every suspicion of partiality, and neutralized every claim of private friendship. They acted as public men ought at all times to act, with no other object in view than the public good.

Commissioners appointed to inquire into abuses.

Subjects of the Reports

(42.) The different Reports of the Commissioners related to the Naval Dock-yards abroad, which it had been long suspected were nurseries of extravagance and fraud; to the peculations practised on those splendid foundations of charity which the piety and patriotism of former Ages had established for the relief of our gallant seamen; to the supply of blocks for the Navy; to the cooper's contract; to the subject of prize agency; to the Sixpenny Office; to the frauds in labour at our Dock-yards,‡ and to the reporting ships as sound that were unsound;* to our Naval Hospitals; to the Victualling department; to the receipt and expenditure of stores; to the Treasurer of the Navy, which led to the resignation and impeachment of Lord Melville; to the issue of Navy bills, and to the purchase of hemp, masts, and fir, for the use of the Navy. All these Reports reflect the greatest honour on their distinguished authors. It required no little perseverance, no little fortitude to pursue in all their detail the great questions which they embraced. Wrapped up in official forms, concealed in all the mystery which men interested in perpetuating frauds know so well how to assume, it required a keen and penetrating eye to detect the evils which a long continuance of bad government had introduced. It was, indeed, time to look into our public departments, and when the service of the Country required so enormous an expenditure, to see that it was properly applied. There is a natural tendency in every thing human to become corrupt; and it is the part of a wise and good Government, by rigid and wholesome checks, to endeavour by every means to prevent it. According to Dr. Colquhoun, the different Naval charges during the reign of George III. amounted to £116,641,862. What a field for peculation and fraud must this enormous sum have afforded! In the single year 1813, there was expended for Naval purposes alone £21,212,011 sterling.

Immense Naval expenditure during the reign of George III.

Imperfect instructions issued to the Dock-yards.

(43.) It may be proper to remark with regard to those Reports which relate more particularly to the Dock-yards, that many abuses doubtless arose from the imperfect regulations and the heterogeneous orders from time to time issued to the officers of the different yards The regulations addressed to the officers in the XVIIth Century, may have been, and probably were, suitable to the then confined state of the Navy; but as the Navy increased, additional instructions were framed to suit its new and more enlarged conditions. These

* The Writer of this Essay, living in the neighbourhood of a Naval arsenal, when quite a boy, remembers well the deep tone of indignation manifested by almost every one connected with our Dock yards, when these important and necessary inquiries were begun.

† The Commissioners were, Vice-Admiral Sir Charles M. Pole, Bart, Ewan Law, Esq., John Ford, Esq., Captain Henry Nicholls, R N, and William Mackworth Praed, Esq.

‡ Much of our successful advancement in the mechanical arts resolves itself into a question of wages. It appears that in our Dock yards, the daily pay of the artificers, when first established in the XVIIth Century, must have been very considerable for the times The settled change in the expense and mode of living, however, had reduced that pay below what was necessary for their support, and had removed every objection to an increase, arising from an expectation of a return to the former state of things. When a rate of pay becomes insufficient from causes of a sudden and extraordinary nature, temporary means may be resorted to; but when the cause is permanent, temporizing expedients, so far from being useful, generally end in conceding to importunity more than, if granted at a proper time, would have been gratefully received. It appears from the history of our Dock-yards that many extraordinary anomalies have existed in this important particular at different times Previous to 1793, the shipwrights were limited in their earnings to 2*s*. 8½*d* a day in Winter, and 3*s* 1*d* in Summer, *the time of their being employed being, in both cases, the common hours of the yard* In 1793, on the contrary, their earnings were limited, both for Summer and Winter, to the constant sum of 4*s*. 2*d*. per day, the time when they were employed being increased, by their being required to work their dinner-time, by which an hour and a half additional labour was obtained. But the common hours of work in Winter being fewer than those in Summer, the pay should not have been the same in both seasons In 1794, the same limit of earnings was continued, but the additional hour and a half was conceded. This gave an increase of 10*d*. a day in Summer, and 1*s* 5½*d* a day in Winter, beyond the limit of prices prior to 1793 One of the inferences deducible from these absurd arrangements is, that the workmen must have been considered as capable of earning, by the same exertions, as much in a less time as in a greater. The Commissioners remark, "that the men could only be made to appear to have earned their full stint in these unequal times of labour, by falsifying the accounts; or, as the officers were left to propose such prices as they might think fit, by their increasing the valuation of the different articles in the same proportion as the Navy Board increased the rate of working, or stint of earnings." The case of the Antelope of 50 guns, built at Sheerness at this time, afforded a practical example of the truth of this position. On a comparison of the expense attending the performance of the works by job, with the sums which would have been allowed if the same works had been performed by task, there appears to have been an excess upon the articles performed by job of nearly one half.

* Every one knows the unfortunate catastrophe that befell the excellent and worthy Flinders. Having entered, as he informs us, the great Gulf of Carpentaria, and surveyed all the projecting capes, creeks, bays, and islands of its Eastern side, it became necessary to calk the ship, when to his great mortification,—and to an ardent mind like his, what mortification could be greater?—the officers reported her to be in such a rotten state as to be wholly unfit to encounter bad weather, and that should she get on shore under any unfavourable circumstances, she must immediately go to pieces; that she was too far gone to bear heaving down on any account; but that in fine weather, and barring accident, she *might* run six months longer. Flinders however determined to complete the survey of the Gulf, and at the end of three months, he was compelled to make another examination of his vessel at Port Jackson. Here the Investigator was found to be so excessively rotten, that she was reported "not worth repairing in any Country, and impossible, in this Country, to be put in a state fit for going to sea." She was, therefore, condemned and sold.

Who, knowing the sufferings and indignities Flinders afterwards endured at Port Louis, but will place them to the account of the careless and ignorant officers who surveyed the "North Country built ship of 334 tons" in which he sailed? The Governor, De Caen, treated him as an impostor and a spy; seized all his books, papers, and charts; placed him in a miserable chamber containing only a truckle bed without curtains, a small table, and a rush-bottomed chair, with a grenadier in the room to watch over him. In this miserable way this virtuous and excellent officer remained a close prisoner for nearly four months.

were often found to be contradictory, and in many instances the regulations of the different yards disagreed. Earl Howe and Sir Charles Middleton, when they presided at the Admiralty and Navy Boards saw the necessity of revising and digesting these orders, and the latter had made some progress in so useful a work when he quitted office. Hence the Commissioners recommended that no time should be lost in reviewing what had been done, in order that the Civil departments of the Navy might, in future, be conducted with order, regularity, and economy.

Consequence of depriving the master shipwrights, &c. of taking apprentices.

(44.) The depriving, by successive regulations, the master shipwrights, their assistants, the foremen, and the quartermen of the privilege of taking apprentices, soon led to some remarkable results. Parents no longer thought of sending sons to the Dock-yards who had received any tincture of a liberal education, since the only persons they could be bound to in order to learn the practice of ship-building were the working shipwrights; and even some regulations were made respecting the privilege these men enjoyed, which had a tendency to lessen the attention they might be expected to give to instruction. The natural result hence followed, that only the very lowest class of the people, and those least likely to have received any education, were induced to enter the Dock-yards. In such a state of things it was hardly to be imagined the superior officers of the yard would feel any interest in the advancement of young men. Accordingly we find in the Report of Naval Revision, "that not one of the apprentices entered in this way had been brought into the mould lofts," where the drawings for ships are executed, and where something like an approach to the principles of the Art might be attained. The reason assigned was, none of the apprentices could be found of suitable education;* so that being without the means of improvement in the Dock-yards, they could not but remain in the same state of ignorance as when their apprenticeship began. It can scarcely be necessary to add," continue the Commissioners, "that unless this part of the present system shall be altered, even good working shipwrights will hardly be found in our Dock-yards; and it would be vain to expect order and regularity in the conduct of the business, accuracy in the accounts, or professional skill in those who must, at no great distance of time, come, of course, to be intrusted with the management of every thing respecting the construction of the ships by which this Country is to be defended." Supposing this course to have been persisted in, it could not but have led to the most disastrous results; it was, in fact, cutting up the very roots of our Naval greatness. "In looking forward," say the Commissioners, "unless some means be taken for the improvement of the education of apprentices, we must not expect a succession of officers or artificers equal to those now in the Dock-yards."

Establishment of School of Naval Architecture.

(45.) This important Report led to the establishment of the School of Naval Architecture at Portsmouth in 1811. It was conceived by the Commissioners that by training up a race of men devoted to Naval Architecture, both in its theory and practice, under the eye of an able Mathematician, important results might fairly be anticipated; and the Government, entering with earnestness and liberality into their views, endeavoured, by every imaginable means, to promote them. The Journals of the day announced that the whole was open to competition. At the head of the Institution was placed the Rev. Dr. Inman, a learned Mathematician, who, in his early days, had obtained the highest honours at Cambridge, and evinced an eminent capability of conducting an undertaking of this kind. During the seven years the students remained at the establishment they were called upon to pursue the study of Geometry in an enlarged way, to carry its beautiful and refined principles into Natural Philosophy, and to enter on the Differential and Integral Calculus. The theory of Naval Architecture was diligently studied, some of the best Continental writers on the subject being diligently read. At the same time the practice of the Art was entered on, and the young men were taught the laying off of ships, and how to prepare every necessary drawing. An excellent practical shipwright (Mr. Fincham) instructed them in all the details of labour at the dock-side; and the adze and the saw were required to be worked with the ardour and spirit of the humblest operative. The object was to make them good theoretical and practical shipwrights, and the Country has a right to expect that they should be so. Of the students admitted at the different public examinations from 1811 to 1822, some have retired from the service, some have died, and twenty-six remain, three of whom have become builders' assistants, others are foremen in the different Dock-yards, and seven remained unprovided for in 1833.*

* These are the official words of the Report. We cannot but observe, however, that prejudice *must* have had some share, perhaps a large share, in this opinion. It can hardly be supposed but that among the mass of apprentices in our Dock-yards, some might have been found worthy of the distinction of entering a mould loft. "Genius," says Washington Irving, "delights in hatching her offspring in by-places;" but it requires the eye of genius frequently to discover it. Had the experiment been tried of a public competition, after suitable notice, among these uneducated youths, there can be little doubt but many would have been found capable of promoting their own intellectual advancement. The great principle of competition remains to be tried in our public departments. The advantages resulting from such a state of things would be immense. At the moment at which we are writing this Note nothing but a dull and melancholy depression is to be met with in the working departments of our Dock-yards.

* We throw into a note a brief notice of the Ordonnance of Charles X. of France, dated 28th March, 1830, relative to the organization of the Royal corps of Naval engineers. (*Géne Maritime.*) It is to consist of the following:—

		Francs.
One inspector-general..................	each	15,000.
Five directors of Naval constructions.......	at Brest, Toulon, and Rochfort.	8000.
	at Cherbourg and Lorient	7000
Ten engineers of the first class		5000
Twelve engineers of the second class		4000
Twelve sub-engineers of the first class		3000
Twelve sub-engineers of the second class ..		2400
Five sub-engineers of the third class		2000

in all 57; and of a number of cadets, to be regulated according to the demands of the service, each to receive annually 1200 francs.

These cadets are to be taken from among those students of the Polytechnic School who are declared worthy of admission into the public services. They are then to pursue for two years at the Port of L'Orient, (under the direction of an engineer of the first or second class, to be nominated by the Minister of Marine,) a complete course of the application of theory to Naval Architecture; to exercise themselves in making drawings of ships of war, and in the details of their masting, sails, fittings, and equipment; to make calculations of displacement, of stability, of the centre of gravity, and all others relative to the theory of Naval Architecture; to investigate the nature of steam-engines and all other machines which may be useful either in the arsenals, or on board ships of war; to design ornamental work, and to study the English Language.

At the expiration of two years, the cadets will be subjected to

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Advantages resulting from the employment of such men as Brunel at our Naval stations.

(46.) It must not be omitted in closing this very brief review of the eventful reign of George III., that we owe to the liberal views of Earl Spencer, who at one time presided at the Admiralty, the devotion of the great talents of Bentham, Brunel, and Barrallier to the public service. That distinguished Nobleman encouraged these eminent men to undertake works most beneficial to the Navy. Before this period, while steam-engines and other powerful machines were abundantly applied in all our manufactories, by a singular fatality they had been wholly neglected in our Dock-yards. Instead of our Naval establishments being schools of practical science, and affording the most perfect patterns of mechanical skill, a dark and imperfect system prevailed of employing only the unaided strength of men and horses. Steam, with all its multiplied applications and powers, was entirely unknown, and docks were pumped, and the heaviest weights raised by mere animal strength. Such men as Brunel cannot but impart new light and intelligence wherever they appear. Born to invent and command, they are destined at every step to add new trophies to the intellectual dominion of Man. Matter assumes new forms, and with the wand of a magician, they seem to rule the elements with it. Hence the unrivalled block-machinery at Portsmouth, exhibiting the most perfect mechanical refinements, and challenging the admiration of the whole world. Had other men, possessing only perhaps a small portion of Brunel's transcendent powers, been encouraged to turn their attention more particularly to Naval Architecture, who could estimate the triumphs that might have accompanied them? It is impossible for a mind accustomed to the higher walks of human thought, to descend to a lower walk of inquiry, without the latter receiving some benefit from the power thus applied to it. At this moment we fear the amount of really *active* practical Science in our Dock-yards is but small.'

Naval Architecture.

George IV.

(47.) Our limits will not permit us to give an account of many important particulars relating to the Navy and Naval improvement which occurred during the closing years of the reign of George III., and that of George IV. The Peace brought with it the repose so much desired; and public men as well as private individuals, no longer having their minds excited by the feverish anxieties of War, had leisure to turn their thoughts to many objects of great importance to our maritime power. Hence many salutary regulations, and the adoption of many important changes, which time has proved to be beneficial, and which it must be our desire to see further perfected and improved. We may refer in this way in terms of the strongest commendation to the labours of Sir Robert Seppings, which will be particularly elucidated in other chapters. The labours of that eminent man, and the immense benefits he conferred on our marine, can never be forgotten, either by the lover of mechanical improvement or the lover of his Country. The introduction of chain cables by Captain Brown has deprived a lee-shore of many of its terrors. Iron tanks, by augmenting the supply of fresh water, have contributed very greatly to the comfort of seamen, and by enabling our fleets to keep longer at sea, have increased their efficiency in a prodigious degree. The Truscott pump has removed the dangerous necessity of getting water-casks on deck; and the abolition of the practice of sending King's stores from the Dock-yards in boats belonging to ships of war, required, as they often were, to do so in tempestuous weather, has preserved the lives of many gallant seamen. The powder also, which by an ancient and dangerous practice was sent on board unfilled, is now received into a ship ready prepared for action. The store-rooms, which at one time exhibited scenes of the greatest irregularity and disorder, present at the present time every thing that can gratify the lover of Naval discipline and order. The wings, or intervals, between the ship's sides on the orlop decks, so necessary to the vigilance and labours of the carpenter during action, and which in seasons gone by were filled with the midshipmen's and quarter-master's hammocks and chests, bags and lanterns,—a receptacle of filth and foul air,—are now kept perfectly clear and clean, as they ought to be.

Improvements of Sir Robert Seppings and others.

Other improvements in the service.

Improvements in signals.

(48.) The science of signals, which has contributed so mainly to our brilliant victories, has also in these latter times been greatly improved. A system which enabled the immortal Nelson to communicate to his whole fleet in the short space of three minutes his splendid and memorable sentence "ENGLAND EXPECTS EVERY MAN TO DO HIS DUTY," cannot but be advantageous. The ships which sailed for India in 1780, possessed merely flags for indicating the most ordinary messages, such as seeing the land, discovering a strange ship, or calling an officer on board. In the War of 1793, Lord Howe's system of tabular signals was employed; and from that time their advance was rapid. In 1795, signal-posts were established on the South coast of England, to indicate the approach of the enemy's cruisers, and to give timely information to our seamen. The land telegraph, connecting the Admiralty with all the sea-ports, produced a celerity of movement quite unknown in former times. The semaphore at present employed in this way was adopted from the French. The sea telegraph was the invention of Sir Home Popham.

an examination in the various branches of instruction they have received. Those who are qualified are immediately to receive the appointment of sub-engineers of the third class, their seniority of rank being fixed by the results of the examination. The sub-engineers of the first and second classes cannot be promoted to the first class until they have made a voyage of at least one year. Specific rules also are laid down respecting the employments of these sub-engineers when on shipboard; these are the details of stowage, the arrangement and effects of the means employed in moving the top masts, top-gallant mast and yards, and also in furling and unfurling the sails, on the working of anchors, on the effects which the shocks of waves and the motions of pitching and rolling have on the combination of the various parts of the structure: and, generally, on every subject relative to Naval construction. They shall keep watch on deck with the most experienced officer on board having charge of a watch.

The following Table of comparative rank is worthy of attentive consideration.

Officers of Naval Engineers.	Officers of the Navy.	Officers of Naval Administration.
Inspector general.	Rear-admiral.	
Director of Naval Constructions.	After the Rear-admirals and before the Post-captains.	Commissary-general.
Engineer, 1st class.	Post-captain (Capitaine de vaisseau.)	Commissary of the Navy.
Ditto, 2d class.	Commander (Capitaine de frégate.)	
Sub-engineer, 1st class.	Lieutenant.	Sub-commissary, 1st class.
Ditto, 2d class.		Ditto, 2d class.
Ditto, 3d class.	Mate. (Enseigne de vaisseau.)	Principal clerks.
Cadet.	Midshipman.	

Uniforms are established for the Naval engineers

Naval Architecture.

William IV.

Abolition of Navy and Victualling Boards.

(49.) By an Act passed in the second year of the reign of King William IV, a very remarkable change took place in the administration of the Civil departments of the Navy. The offices or departments of the principal officers and Commissioners of the Navy, and of the Commissioners for victualling the Navy, and for the Care of Sick and Wounded Seamen, were entirely abolished; the powers and authorities heretofore vested in these Boards being transferred to the Admiralty.

Change of officers at the Dock-yards.

By the same Act, the duties hitherto performed by Commissioners at the several Dock-yards and other Naval and Victualling establishments at home and abroad, are in future to be executed by officers called Superintendents; the Commissioners of the Admiralty and the Superintendents being empowered to administer oaths and execute the duties of Justices.

One general account opened at the Bank for the Navy.

With regard to the important article of expenditure, it was enacted that one general account should be opened at the Bank of England for Naval services; and annual accounts be made up and certified, together with rigid annual inspections of all monies remaining with the Treasurer of the Navy, his cashiers and clerks. Monthly accounts also are to be furnished from the several Dock-yards. The Admiralty also is enjoined to make up an annual account of expenditure, under the heads of service specified in the Appropriation Act, the Commissioners of Audit being empowered to examine the same, and to lay a copy thereof before Parliament.

Officers connected with the Civil departments of the Navy.

(50.) At the present time the various officers connected with the Civil departments of the Navy are the following: seven Commissioners for executing the office of Lord High Admiral of the United Kingdom of Great Britain and Ireland, with two Secretaries, and senior and junior clerks. Several principal officers, *viz.* a Surveyor of the Navy, an Accountant-General, a Storekeeper General, a Comptroller of the Victualling of the Navy and of the Transport Service, Physician of the Navy, and a Civil Architect. Connected with the Navy Pay Office, there is a Treasurer of the Navy, with various subordinate officers relating to the Wages, the Bill, Ticket, and Allotment branch, the Navy Bill branch, the Victualling Bill branch, &c.

Navy estimates.

Estimate for 1833–1834.

(51.) The Navy estimates, in future, are to be arranged as follows:

Nos. Required for the Service of the year 1833–1834.

Nos.			£	s.	d.
1. Wages	of seamen and marines	£871,550	955,220	0	0
	of the ordinary, yard, craft, &c.	83,670			
2. Victuals	of seamen and marines	103,650	438,004	0	0
	Abate "Old stores"	7,830			
		395,820			
	of the ordinary, yard, craft, &c.	12,184			
3. Admiralty Office			101,070	0	0
4. Navy Pay Office			21,725	0	0
5. Scientific branch*			22,109	0	0
6. His Majesty's establishments at home			114,970	0	0
7. His Majesty's establishments abroad			25,122	0	0
8. Wages to artificers, &c. employed in His Majesty's establishments at home*			438,426	0	0
9. Wages to artificers, &c. employed in His Majesty's establishments abroad			26,905	0	0
10. Naval stores, &c. for the building and repair of ships, docks, wharfs, &c.†			123,600	0	0
11. New works and improvements in the yards, &c.			63,700	0	0
12. Medicines and medical stores			31,500	0	0
13. Miscellaneous services			50,380	0	0
Total for the effective service			£2,713 131	0	0
14. Half-pay to officers of the Navy and Royal Marines‡			871,858	0	0
15. Military pensions and allowances			533,103	0	0
16. Civil pensions and allowances			220,342	0	0
Total for the Naval service			£4,339,031	0	0
For the Service of other Departments of Government.					
17. Army and Ordnance departments (conveyance of troops, &c.)			200,800	0	0
— Colonial department			—	—	—
18. Home department (convict service)			118,300	0	0
Grand Total			£4,658,131	0	0

* It is worth while to give in a note an abstract of the scientific branch:

	£	s.	d.
Royal Naval College and School for Naval Architecture			
Royal Observatory	2,750	1	0
Observatory at the Cape of Good Hope	1,020	0	0
Nautical Almanack	4,160	0	0
Chronometers	1,700	0	0
Rewards, experiments, &c.	1,000	0	0
Hydrographical department	11,199	12	0
Extra pay for exploring the Quorra and Southern Continent	259	4	0
Libraries and Museum at Haslar and Plymouth Hospital	1,100	0	0
Gratuity to Mr. Grant for his Biscuit Manufactory	2,000	0	0
Total	£22,109	0	0

* The wages to artificers and labourers *at home* to those *abroad*, are to each other in about the ratio of *sixteen* to *one*.

Dutch Auction.

† The mode of disposing of old ships and stores in his Majesty's Dock-yards by what is called Dutch Auction, deserves an explanation. The article to be sold is put up by an officer at some price previously fixed on. He then progressively lowers the sum, until some one says *mine*, when it is knocked down to the speaker, or he becomes the purchaser. Certain conditions are in most cases entered into by the purchaser, in the case of ships, that they are to be broken up within twelve months of the day of sale. This was the case with the San Antonio, Phaeton, and Virginia in the succeeding Table. Copper bolts marked with the King's broad arrow ↑ are also to be returned, the purchaser receiving a fair value for them in return. The following Table will give the particulars of a sale of several ships of war, on the 11th of July, 1827, at Somerset House, in presence of three Commissioners of the Navy.

Name of ship.	Guns or class.	Tonnage.	Place where the ship was lying.	Price at which it was put up by the Commissioners.	Price at which it was sold.
Pheasant	22	365	Deptford	£1100	[illegible]
Bann	Sloop	466	Chatham	[illegible]	[illegible]
Belette	Brig	386	Ditto	[illegible]	[illegible]
San Antonio	74	1700	Portsmouth	[illegible]	[illegible]
Phaeton	46	941	Ditto	[illegible]	[illegible]
Argus	Brig	387	Ditto	[illegible]	2000
[illegible]	Cutter	145	Ditto	[illegible]	[illegible]
Scout	Brig	382	Ditto	1560	1010
Quail	Cutter	82	Ditto	700	110
Virginia	38	1066	Plymouth	3500	[illegible]
Petrel	Sloop	365	Ditto	1160	[illegible]

‡ The original Orders in Council bestowing half-pay on Naval officers, required them to reside in the sea ports, and to assist in fitting out ships. Half-pay was hence a payment for service performed in time of Peace.

Admirals and Captains were first appointed Generals and Colonels of Marines in 1759, soon after the Battle between Hawke and Conflans. The first General of Marines was Admiral Boscawen, and the first Colonel Sir P. Brett.

The Naval sinecure offices amount only to the annual sum of £7750: and every name in the subjoined list is distinguished by the most brilliant services. It is the honour of being associated with the great commanders who have held these posts, more than the actual emoluments arising from them, that render them

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This account, it should be remembered, has reference to a period of profound Peace, of rigid and unrelenting economy, and when every means are taken to reduce all the public establishments to a minimum of expense.*

Our limits will not permit us to give more than a brief analysis of this important statement, referring to the Navy Estimates themselves for more detailed information.

Naval establishments at home.

(52.) The establishments at home connected with the Navy consist of NAVAL YARDS, VICTUALLING ESTABLISHMENTS, MEDICAL ESTABLISHMENTS, TRANSPORT ESTABLISHMENTS, MARINE BARRACKS, AND MARINE INFIRMARIES.

(53.) The Naval yards are at Deptford, Woolwich, Chatham, Sheerness, Portsmouth, Plymouth, Pembroke, Deal, North Yarmouth, and Kingstown. The Victualling establishments are those of Deptford, Sheerness, Portsmouth, Plymouth, Haulbowline, Brixham, Staddon Point, Milor, Deal, and Dover. The Medical establishments are Haslar and Plymouth. The Transport establishments are Deptford, Portsmouth, Leith, and the Cove of Cork. Marine barracks are found at Woolwich, Chatham, Portsmouth, and Plymouth; at which places also are the Marine infirmaries.* The total sum voted for the financial year

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objects of honourable ambition. It is worthy also of record, that *no offices* whatever are executed by deputy in the Navy.

Description of Office.	Salary, Pay, and Allowances received. £. s. d.	Date of Appointment.	Rank of Officer holding the Office.	Where employed.	How long employed in active service. Years.
Vice-admiral of England..	469 5 8 a year.	30 Jan. 1833.	Sir Edward Thornbrough, Admiral of the Red, G.C.B.	In various parts of the world afloat	49½
Rear-admiral of England..	370 4 3	24 ditto.	Sir George Martin, Admiral of the White, G.C.B.	Ditto.	33
General of Marines	1728 15 0	13 Feb. 1832.	Lord De Saumarez, Admiral of the Red, G.C.B.	Ditto.	47
Lieut.-General of Marines..	1383 0 0	23 June, 1830.	Sir William Sidney Smith, Admiral of the White, K.C.B.	Ditto.	21
Major-General of Marines..	1037 5 0	5 April, 1821.	Right Hon. Sir George Cockburn, Vice-Admiral of the Red, G.C.B.	Ditto.	29
Colonel of Marines	690 9 2	22 July, 1830.	William Skipsey, Captain Royal Navy	Ditto.	34
Ditto ditto	690 9 2	Ditto.	Hon. Frederick Paul Irby, Captain Royal Navy, C.B.	Ditto.	21
Ditto ditto	690 9 2	Ditto.	Sir Christopher Cole, Captain Royal Navy, K.C.B.	Ditto.	32
Ditto ditto	690 9 2	Ditto.	Hon. Duncan Pleydell Bouverie, Captain Royal Navy.	Ditto.	23

Admiralty, 27th February, 1833.

French Marine Budget.

* The following is an abstract of the Budget of the French Minister of Marine and Colonial Affairs for the year 1829

	Francs.
Salary of the Minister, of Directors and subdirectors, Prefects of Marine, officers on shore, *équipages de ligne* on shore, Marine artillery, Naval engineers, Officers having charge of Commissariat, Chaplains, Medical staff, Professors in Navigation Schools, of persons employed in felling timber in French Guianne, Storekeepers, &c. Officers of Hulks, and persons employed in the Royal Founderies..........	11,791,876
Pay of General Staff at sea, of the crew of one ship of the line, ditto of the crews of 127 vessels, containing 12,410 men, and expense of clothing the *équipages de ligne*, fuel for the *troupes de la marine*, barracks, &c.	7,863,800
Expense of Marine hospitals for sick mariners	1,181,500
Ditto of provisions	6,834,500
Pay of workmen, expense of ship-building, materials, and artillery	23,621,300
Expense of docks, &c.	3,800,000
Expense of the galley slaves	312,400
Miscellaneous expenses	692,000
Expenses of the Army and Navy in the colonies....	6,000,000
Total ..	63,109,976

In 1823 a Royal Ordonnance was promulgated for establishing a distinct body of seamen to serve on ship-board or in the Naval arsenals, to be called *équipage de ligne*. This body is divided into separate corps, each corps being composed of a permanent Staff of ten persons, and of four companies of 150 men each.

All the Officers of the Royal Navy, from the rank of *Enseigne de vaisseau* to that of *Capitaine de frégate* inclusive, must be employed in the *équipage de ligne*, and serve in it two years successively, unless they receive orders to the contrary from the Minister of Marine. Every seaman belonging to the *équipages de ligne* must be instructed and rendered fit to perform all duties whatever which relate to the manoeuvring, piloting, serving at the guns, or repairing of a vessel, together with the manual exercise as a Marine on ship-board or in the Naval arsenal. The men of the *équipages de ligne* are employed in all vessels from a ship of the line to a 16 gun brig inclusive. See Goldsmith's *Statistics of France*, London, 1832.

Navy disbursements of the United States

The amount disbursed annually in the Navy establishments of the United States is about three millions and a quarter of dollars, a considerable portion of which is devoted to its gradual improvement, by the accumulation of stores, the creation of dry docks, and the building of additional vessels.

The following is an account of the principal elements of expenditure for 1829.

	Dollars.	Cts.
Pay and subsistence of the Navy afloat ...	1,160,068	09
Ditto ditto shore stations	161,830	26
Pay of superintendents, artificers, &c.......	62,222	56
Provisions	461,636	83
Medicines and hospital stores.............	25,772	60
Repairs and improvements of Navy yards ..	148,989	09
Ordnance and ordnance stores............	26,262	61
Gradual improvement of the Navy	444,395	98
Repairs of vessels.......................	470,945	68
Labourers and fuel for engine	1,660	45
Pay and subsistence of the Marine corps	117,329	19

These various sums, together with other different expenses, form a grand total amount of 3,308,745 dollars 47 cents.

* It was once the practice to employ officers of the Army in the Marine service, and the Marines themselves were privates of the Army. In all the great actions before Cromwell's time, and during the time of the usurper, soldiers were constantly embarked as Marines.

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1833—34 for the pay of the various officers connected with these establishments, taxes, and other incidental expenses amounted to £114,970.

Naval establishments abroad.

(54.) His Majesty's establishments abroad consist of NAVAL YARDS, VICTUALLING ESTABLISHMENTS, MEDICAL ESTABLISHMENTS, and TRANSPORT ESTABLISHMENTS.

(55.) The Naval yards are at Gibraltar, Malta, Canada, (Kingston and Montreal,) Halifax, Newfoundland, Bermuda, Antigua, Jamaica, Sierra Leone, and Fernando Po, Cape of Good Hope, and Trincomalee. The Victualling establishments are at Gibraltar, Malta, Halifax, Bermuda, Jamaica, Bahamas, Barbadoes, Ascension, Sierra Leone, Fernando Po, Cape of Good Hope, and Rio de Janeiro. The Medical establishments are found at Malta, Halifax, Bermuda, Jamaica, and Cape of Good Hope. A single Transport establishment exists at Gibraltar. The total sum voted for the financial year 1833—34 was £23,422.

Officers of Portsmouth Dock-yard.

(56.) We can only give a brief enumeration of the officers of one of each of these establishments. Taking Portsmouth Dock-yard as the first and most important at home, we in the first place remark, that it is governed by an Admiral Superintendent, the other principal yards having only a Captain Superintendent presiding over them.* The officers next in rank are a master attendant and assistant; a master shipwright and two assistants; a storekeeper, store receiver, surgeon and assistant, a chaplain, timber converter, boatswain, and warden, together with twenty-seven clerks. Also masters for the smiths, sail-makers, riggers, and rope-makers; ten foremen of the yard; two conductors of the wood and metal mills; foremen for the millwrights, metal mills, rope-makers, and smiths; two assistant timber converters, and twelve measurers.

Victualling establishment at Deptford.

(57.) Of the Victualling establishments, we select Deptford, which has a Captain Superintendent, a storekeeper, a master attendant of the wharf and assistant; a surgeon and assistant; fourteen clerks; a master cooper, master miller, and master baker; a warden; two foremen of coopers, and four foremen of stores, together with an engineer.

Plymouth Hospital.

(58.) Of the Medical establishments we take that of Plymouth Hospital, which is governed by a Captain Superintendent, who attends, also, to the Victualling establishment, assisted by two lieutenants; there is also attached a physician, a surgeon, an agent and steward, a dispenser, a chaplain, three clerks, and four hospital mates.

Marine barracks.

(59.) To the Marine barracks are attached a barrack master, barrack sergeant, and barrack clerk; and to the Marine infirmaries belong a surgeon and two assistants, a purveyor, a chaplain, and a quarter-master.

Naval yard at Malta.

(60.) Of the establishments abroad, we take the Naval yard at Malta, which has an Admiral Superintendent, a Naval storekeeper, a master attendant, master shipwright, clerks, boatswain, and foreman of shipwrights. To the Victualling establishment at the same place there is attached an agent victualler and clerks; and to the Hospital, a surgeon, dispenser, hospital mate, chaplain, and clerk.†

* The Superintendents of the Dock-yards were formerly Civil situations, the persons filling them being styled Commissioners. They are not at this time so considered. The alteration took place on the 1st of June, 1832.

† Where there is no Superintendent, the Commander in Chief is, as far as may be in his power, to see that every officer punctually obeys the orders and instructions he shall have received from the Lords Commissioners of the Admiralty. The Commander in Chief in such a case is to conform to the established rules and general practice of the Navy. He is also to receive from the storekeeper, and every other person intrusted with the charge of money, three general statements of their respective accounts quarterly, which he is to examine and certify.

Wages of shipwrights, &c. at the several Dock-yards.

(61.) For the wages of shipwrights, other artificers, and labourers employed in the Dock-yards at home, during 1833—34, there were paid the following sums:

Woolwich	£53,500
Chatham	65,500
Sheerness	28,000
Portsmouth	108,400
Plymouth	113,000
Pembroke	21,000
Deal } Haulbowline }	600
Making a total of	£390,000

Important question of labour.

(62.) The question of labour in the Dock-yards has occupied much of the attention of the Admiralty and of the late Navy Board. While the Country loudly called for retrenchment, the members of these Boards were anxious to effect it with the least possible privation to individuals. In January 1830, it was resolved that the payment of chip money should cease, and that no more men or apprentices should be entered in the yard, in lieu of others dying or discharged, until the number should be reduced to 6000, the number to be preserved during Peace. As soon as the number should be brought down to 7000, the men were to be allowed to work the whole of Wednesday, and when reduced to 6500 to work six days in the week. These arrangements prove the anxious desire of the Admiralty for the welfare of the workmen. The following Table will give the total establishments borne on the books of the Dock-yards at home in the years mentioned in it.

Total number of workmen and apprentices.

	Inferior Officers.	Workmen.	Apprentices.	Total.
Jan. 1, 1830 ...	213	7068	648	7929
Jan. 1, 1831 ...	197	6560	633	7390
Jan. 1, 1832 ...	172	6505	524	7201

Great change in the system of labour.

(63.) During the year 1833, however, an entire change of system has taken place in the Dock-yards respecting labour, with the view of economizing the consumption of the public stores. The jobbing, or contract plan hitherto adopted has been abolished, and the men have been placed under an entirely new system of classification.

Abolition of contract work.

The practice of contract work grew out of the necessities of the War, when extra labour was almost daily called for; but the system has been found productive of great public loss. It has been said, and we believe with great truth, that when men are paid according to the quantity of work done, they are not very scrupulous about the conversion of materials, and thus an immense waste of public stores has been the consequence.

Waste of materials.

To remedy this evil, the present Board of Admiralty resolved to return to the old plan of fixed allotted work and daily pay; and there existing no necessity for urgent despatch in time of Peace, the present has been selected as a proper period for effecting a change. At the same time, also, it was resolved that superannuations should be abolished.

(64.) As a curious and important document respect-

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ing the distribution of labour in the Dock-yards, and showing the relative importance of the different trades employed in them, we add the following valuable Table drawn up by the Navy Board on the supposition that the workmen were reduced to 6000. We regret that our limits will not permit us to dilate upon this important document.

Table of the distribution of workmen.

Description.	Deptford.	Woolwich.	Chatham.	Sheerness.	Portsmouth.	Plymouth.	Pembroke.	Total.
Blockmakers	..	1	1	2	3	3	..	10
Boys, House	..	..	20	..	20	20	..	60
Ocham	..	3	6	3	8	8	2	30
Wheel	..	..	..	..	..	12	..	12
Braziers, tinmen, and apprentices	2	4	6	4	8	8	..	32
Bricklayers and apprentices	..	6	8	6	12	12	..	44
Labourers	..	2	3	3	4	4	..	16
Calkers and apprentices	..	16	30	40	50	50	14	200
Coopers	1	1	1	4	1	1	..	9
Engine repairers	..	3	..	..	..	..	..	3
Founders	..	..	..	..	2	..	..	2
Hemp-dressers	..	..	..	..	..	16	..	16
Joiners and apprentices	..	44	80	43	106	100	40	413
Key-beaters (ropery)	..	..	1	..	1	1	..	3
Labourers, store house	19	11	14	10	14	14	3	85
Yard	4 as boatmen	40	80	40	100	100	40	404
Line and twine spinners	..	..	..	..	..	14	..	14
Locksmiths and apprentices	..	1	2	1	2	2	..	8
Masons and apprentices	..	.	2	2	10	10	10	34
Messengers	2	4	5	4	6	6	2	29
Millwrights	..	2	2	2	..	2	..	8
Plumbers and apprentices	1	2	4	2	4	4	..	17
Painters, glaziers, and apprentices / Grinders / Labourers	1	6	14	16	20	20	4	81
Pitch heaters	..	1	1	1	1	1	1	6
Riggers	..	20	20	40	50	50	..	180
Labourers	..	6	6	12	13	13	..	50
Sailmakers and apprentices	20	1	36	1	36	36	1	131
Sawyers	..	60	80	60	100	100	60	460
Scavelmen	1	10	10	10	20	20	..	71
Shipwrights and apprentices	3 (2 as house carpenters)	200	500	300	650	650	200	2503
Smiths and apprentices	1	50	80	50	110	120	50	461
Spinners and apprentices	..	..	136	..	136	136	..	408
Warders	3	10	13	18	20	20	6	90
Wheelwrights	..	1	2	1	3	2	1	10
Workmen at Wood mills	..	..	..	..	20	..	..	20
Metal mills	..	..	..	..	40	..	..	40
Millwright's shop	..	..	..	..	40	..	..	40
Total	58	505	1163	675	1610	1555	134	6000

Of the shipwrights above stated, *viz.* 2500,* a considerable number will be employed as house carpenters, (that description of artificers having been abolished) and in other inferior trades; the object being to retain as many shipwrights as possible at the same expense as persons of those descriptions would be paid in working at their own trades.

Expense of warders, watchmen, &c.

(65.) The annual expense of warders, watchmen, and rounders, in the Dock-yards last adverted to, amounted for 1833 - 34 to £11,676, a great but necessary sum. While this Essay has been passing through the press, an important change has been made. A regular and systematic Police has been established* in the

New system of Police.

* The 2500 shipwrights here alluded to, would complete annually, fit for launching, fifteen 120-gun ships; twenty 80-gun ships; twenty-six seventy fours, thirty-six double-banked frigates of 52 guns, or seventy corvettes of 28 guns.

In the reign of Charles I Mr Phineas Pett speaks of hiring and victualling the shipwrights and calkers, on several occasions, and of their being discharged when the work for which they were hired was performed. The victualling of workmen forms a singular contrast with the customs of the present day It is not known when this practice was given up. It is supposed that there was a small permanent establishment of artificers in each of the existing Dock-yards for ordinary purposes.

In the reign of Queen Anne, the maximum number of shipwrights in the several Dock-yards amounted to 2574, exceeding the number admitted at present to be necessary; the minimum number during that reign was 1678.

In the period from 1744 to 1805 inclusive. the greatest number of shipwrights were employed in 1800, amounting to 3776. The least number was in 1755, amounting to 2305. In 1803 the number was 2878.

* It appears that a Central Board of Police was strongly recommended by the Select Committee of the House of Commons on Finance, in their 28th Report. printed in June 1798. It was then proposed to bring under regulations by licenses, all dealers in old and second-hand ship's stores, old iron, and other stores, and several other dangerous and suspicious trades, the uncontrolled exercise of which, by persons of loose conduct, is known to contribute to the concealment and multiplication of crimes. Dr. Colquhoun, however. remarks in addition, that salutary as this Central Board must certainly be in controlling and checking the Naval plunder, in common with the general delinquency of the whole Country. it would seem indispensably necessary, under circumstances where the moving property is so extensive, and where there exist so many resources and temptations leading to the commission of crimes, to fix on some one person the responsibility of carrying the laws into effect, and of controlling and overawing the various classes of delinquents,

Great plunder formerly in the Dock-yards.

Dock-yards of Chatham and Sheerness, and doubtless will be extended to the other yards. The former history of our Dock-yards is indeed a history of plunder and fraud.* It is true that, in later times, things have been better; but the plunder of several tons of copper, even within the last two years, no traces of which were detected before the metal had reached Birmingham, proves there is still something defective; something which a vigilant Board of Admiralty ought to correct.

Prevention of crime the great principle to be observed.

(66.) We have now before us a printed copy of the Police Instructions, the fundamental principle of which is "*the Prevention of Crime;*" a principle salutary in itself, and calculated, if followed out in all its consequences with energy and effect, to produce the most beneficial results. It does not appear that the arrangements are yet perfect respecting this important change; but the admission of the necessity of a change, the beginning that has been already made in breaking up the old system, the putting new and altered powers into motion, cannot but be advantageous.

Classes and denominations of Royal Navy.

(67.) The Royal Navy is divided into the following classes and denominations.

1. Rated ships, *viz.*

First rate, all three-decked ships.

Second rate, one of his Majesty's yachts, and all two-decked ships of 80 guns and upwards.

Third rate, his Majesty's other yachts, and all ships of 70 guns and less than 80.

Fourth rate, ships of 50 guns, and less than 70.

Fifth rate, ships of 36 guns, and less than 50

Sixth rate, ships of 24 guns, and less than 36.

2. Sloops and bomb vessels.

3. Gun brigs, cutters, schooners, and other small vessels.*

Erroneous system which formerly prevailed.

(68.) These different classes and denominations are doubtless very proper, and experience has proved, that many advantages result from ships of different magnitudes; but there can be no possible reason why ships of the *same* rate should vary so much in size. When Nelson was off Cadiz with seventeen or eighteen sail of the line, he had no less than *seven* different classes of 74-gun ships, each requiring different masts, sails, yards, &c., so that if one ship was disabled, the others could not supply her with appropriate stores. No state of things could possibly be more deplorable than this, and to an acute and sensitive mind like Nelson's, it must have been a source of the deepest regret. In the reign of James I. the classes of ships were, ships royal, great ships, middling ships, small ships, and pinnaces. Ships were first distinguished by rates in the reign of Charles I.

Amount of the Royal Navy on the 1st of October, 1833.

(69.) The Royal Navy on the 1st of October, 1833, consisted of 557 ships of all classes. Of these, fourteen were of 120 guns, five of 110 guns, three of 108 guns, twelve of 84 guns, ten of 80 guns, nine of 78 guns, six of 76 guns, sixty-two of 74 guns, seven of 52 guns, fifteen of 50 guns, sixty-two of 46 guns, twenty of 42 guns, and twenty-two steamers; the remaining ships varying from 30 to 4 guns.†

whose attention is directed to the Dock-yards as a means of obtaining plunder. In the Work on the Police of the Metropolis, we find a section named, *A Local Police for the Dock-yards.*

* Dr. Colquhoun remarks, that the abuses, frauds, and embezzlements are multifarious, and are perpetrated through the medium of a vast variety of agencies, which naturally divide themselves into two distinct branches.

The first relates to frauds committed by the connivance and assistance of clerks, storekeepers, and inferior officers in the Dock-yards, and other repositories, and in ships of war and transports, in receiving and delivering Naval, Victualling, and Ordnance stores; in surveys, in returns of unserviceable stores, in what is called solving of stores, in fraudulent certificates, in the sale of old stores, and innumerable other devices.

The second branch relates to the actual pillage of new and old cordage, bolts of canvass, sails, bunting, twine of all sorts, fearnought and kersey leather and hides, old and new coppers, locks, hinges and bolts, copper bolts and nails in immense quantities, bar iron, old iron, lead and solder, ship's plank, oars, timber of small sizes, blocks, quarterstuff, candles, tallow, oil, paint, pitch, tar, turpentine, varnish, rosin, beer and water casks, iron hoops, biscuit bags, beer, bread, wine, brandy, rum, oil, vinegar, butter, cheese, beef, pork, &c.

Many vessels in the coasting trade, and even ships of foreign nations, it is said, touch at Portsmouth and Plymouth, merely for the purpose of purchasing cheap stores.

The artificers in the Dock-yards, availing themselves of their perquisite of chips, not only commit great frauds, by often cutting up useful timber, and wasting time in doing so; but also in frequently concealing, within their bundles of chips, copper bolts, and other valuable articles, which are removed by their wives and children, (and as has appeared in judicial evidence, by boys retained for the purpose,) and afterwards sold to itinerant Jews, or to the dealers in old iron and stores, who are always to be found in abundance wherever the Dock-yards are situated.

Among the multitude of persons concerned in these fraudulent transactions, some are said to keep men constantly employed in untwisting the cordage for the purpose of removing the King's mark, or coloured straw, which is introduced into it as a check against fraud; while others are, in like manner, employed in cutting the broad arrow out of copper bolts, nails, bar iron, and other articles, on which it is impressed, so as to elude detection.

These remarks are from the Doctor's Work on the Police of the Metropolis, edition 1806, and relate to a time of War. Things are very much mended now, but we decidedly approve of a local Police for the Dock-yards.

* Whenever any of His Majesty's ships or vessels are fitted as steam-vessels, troop-ships, surveying-ships, fire-ships, prison-ships, hospital-ships, store-ships, and victualling-ships, or for any other temporary service, the Lords Commissioners of the Admiralty may assign to them such rate or class, not above a fourth-rate, as they may judge proper.

French Navy in 1831.

† The French Navy in 1831 consisted of the following:—thirty-five ships of the line of three rates, forty frigates of three rates; twenty-three corvettes of from 18 to 32 guns; fifty-seven brigs of from 8 to 20 guns; eight bombs; galliots and cutters, eighteen of 8 guns; forty-one of 4 guns; twelve steam-boats, sixteen armed store-ships, thirty-two armed transports, and two yachts, amounting in all to 284 vessels fit for sea, whether in commission or lying in ordinary. At the same time, also, there were twenty ships of the line and twenty-six frigates building, besides several corvettes, brigs, steam-boats, and store-ships. There were also to be put on the stocks in 1832, three ships of the line, two third-rate frigates, three corvettes, and five steam-boats.

Navy of United States in 1830.

In 1830 the United States' Navy consisted of seven sail of the line, all of which were laid up in ordinary; seven frigates of the first class, of which three were in ordinary and four in commission; three frigates of the second class, of which one was a receiving-ship, one in actual service, and one in ordinary; fifteen sloops, of which two were in ordinary, and the remainder on different foreign stations; seven schooners, of which three were in employ as receiving-ships, one in ordinary, and two in commission. There were also five ships of the line and seven frigates in such a state of forwardness that they could be ready for sea in three months. There are seven Navy yards maintained by the Government in different States of the Union. In the Secretary's Report an allusion is made to the construction of two dry-docks, "seldom rivalled in beauty and solidity." The expenditure on each has been 500,000 dollars. A great progress has been made in constructing buildings for the accommodation of officers of the yards, in storehouses, sheds, wharfs, walls, and shipways. Rope walks also are contemplated. The vessels in ordinary have been covered at most of the yards, to shelter them from sunshine and storms. The purchase of timber and stores under the Act for the gradual increase of the Navy, remaining in the yard, amount to a million and a half. The amount of property on hand for repairs is almost a million. The ordnance, provisions, &c., amount to upwards of a million and a half.

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Number of ships in commission

(70.) Of these there were in commission 126, *viz.*, five three-deckers, varying from 104 to 120 guns, eight second and third-rates, varying from 74 to 84 guns; seven fourth-rates of 50 guns; eight fifth-rates, varying from 36 to 46 guns; sixteen sixth-rates, varying from 24 to 28 guns; thirty sloops, varying from 16 to 20 guns; and nineteen 10-gun brigs; the remainder being small vessels carrying from 2 to 8 guns. The sailors required for this force amount to 20,000, and the Marines 9000. The Marines thus amount to nearly half the seamen. In 1793 they amounted to only one-seventh; but in the latter part of the War the proportion rose to considerably more than one-fifth.

Classes of officers in the Royal Navy.

(71.) The Officers of his Majesty's Navy are divided into three classes, *viz.*, Commission officers, Warrant officers, and Petty officers.

The Commission officers are of the undermentioned denominations, and take precedence and rank in the following order:—Flag officers, Commodores, Captains, Commanders, and Lieutenants.*

Warrant officers are of the following denominations, which also represent the order of their respective ranks:—

1. Masters,
2. Secretaries,
3. Physicians,
4. Chaplains,† } To rank with Lieutenants, of the Navy, but to be subordinate to them.
5. Surgeons,
6. Pursers,
7. Mates.
8. Second masters.
9. Assistant-surgeons.
10. Gunners.
11. Boatswains.
12. Carpenters.

The Petty officers arranged according to their ranks are the following:—

1. Schoolmaster.
2. Clerks.
3. Masters at arms.
4. Ship's corporals.

(72.) The following Table contains an analysis of the various classes and denominations of the officers and men for the several rates of our ships, and furnishes a good idea of the beautiful economy that prevails in this great and important particular.

Classes for Distribution of Seizures.	Ranks and Ratings.	First Rate.	Second Rate.	Third Rate.	Fourth Rate.	Fifth Rate.	Sixth Rate.	Sloops. 100 Men, and upwards.	Sloops. Under 100 Men	Bombs	Gun-Brigs, Schooners, and Cutters.
		No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
I.	Captain	1	1	1	1	1	1	..	..	1	
	Commander	..	..	..	..	..	..	1	1	..	
II.	Lieutenants of seven years' standing and	8	7	6							
	All other Lieutenants				5	4	3	2	2	2	1
	Master	1	1	1	1	1	1	1	1	1	1
III.	Chaplain	1	1	1	1	1	1				
	Surgeon	1	1	1	1	1	1	1	1	1	
	Purser	1	1	1	1	1	1	1	1	1	
	Second Master	1	1	1	1	1	1				
	Assistant Surgeon	3	3	2	2	1	1	1	1	1	1
	Gunner	1	1	1	1	1	1	1	1	1	
	Boatswain	1	1	1	1	1	1	1	1	1	
	Carpenter	1	1	1	1	1	1	1	1	1	
IV.	Mate / Midshipman (First Class Petty Officers)	24	20	16	10	8	6	2	2	2	1
	Master's Assistant	6	6	6	4	4	4	2	2	2	2
	Schoolmaster	1	1	1	1	1	1				
	Clerk	1	1	1	1	1	1	1	1	1	1
	Master at Arms	1	1	1	1	1	1				
	Admiral's Cockswain										
	Ship's Corporal	2	2	2	2	2	1	1	1	1	
	Captain's Cockswain	1	1	1	1	1	1	1	1	1	
	Quarter Master	12	12	9	6	5	3	3	2	2	1
	Gunner's Mate	5	4	3	2	2	2	2	2	1	1
	Boatswain's Mate	8	7	6	4	3	2	2	2	1	1
	Captain of Forecastle	3	3	3	2	2		2	1	1	
	Captain of the Hold	1	1	1	1	1					
	Cockswain of the Launch	1	1	1	1	1					
	Ship's Cook	1	1	1	1	1	1	1	1	1	1
	Sail Maker	1	1	1	1	1	1	1	1	1	1
	Rope Maker	1	1	1	1	1	1	1	1		
	Carpenter's Mate	2	2	2	2	2	1	1	1	1	
	Calker	1	1	1	1	1	1	1	1		
	Armourer	1	1	1	1	1	1	1	1	1	

* Relative rank of Officers of the Navy and Army.
1. Admirals of the Fleet with Field-marshals of the Army.
2. Admirals with Generals.
3. Vice-admirals with Lieutenant-generals.
4. Rear-admirals with Major-generals.
5. Commodores with Brigadier-generals.
6. Captains after three years from the dates of their first commissions for rated ships with Colonels.
7. All other Captains with Lieutenant-colonels.
8. Commanders with Majors.
9. Lieutenants with Captains.
10. Masters with Junior Captains.

† It is very gratifying to read the strict and earnest injunctions enforced on the attention of the Chaplain in the Admiralty Instructions respecting his important duties. To instruct, to be attentive, to be very assiduous, are terms applied to all the different branches of his duty; displaying an anxious concern for the religious, moral, and intellectual welfare of all on board.

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Classes for Distribution of Seizures.		Ranks and Ratings.	First rate.	Second rate.	Third rate.	Fourth rate.	Fifth rate.	Sixth rate.	Sloops: 100 Men and upwards.	Sloops: Under 100 Men.	Bombs	Gun-brigs, Schooners, and Cutters.
			No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
V.	Second Class Petty Officers.	Captain of the Maintop	3	3	3	2	2	2	2	1		
V.	Second Class Petty Officers.	Captain of the Foretop	3	3	3	2	2	2	2	1	1	
V.	Second Class Petty Officers.	Captain of the Mast	3	3	3	2	2	2	1			
V.	Second Class Petty Officers.	Captain of the Afterguard	3	3	3	2	2	2	1			
V.	Second Class Petty Officers.	Yeoman of Signals	1	1	1	1	1					
V.	Second Class Petty Officers.	Cockswain of the Pinnace	1	1	1							
V.	Second Class Petty Officers.	Sailmaker's Mate	1	1	1	1	1	1				
V.	Second Class Petty Officers.	Calker's Mate	1	1	1	1						
V.	Second Class Petty Officers.	Armourer's Mate	2	2	2	1	1	1	1	1		
V.	Second Class Petty Officers.	Cooper	1	1	1	1	1	1	1	1	1	1
V.	Second Class Petty Officers.	Volunteer of First Class	8	7	6	4	4	3	3	2	1	1
V.	Second Class Petty Officers.	Volunteer of Second Class	4	4	4	3	3	2	2	2	1	1
VI.		Gunner's Crew	25	22	20	13	10	8	6	4	1	2
VI.		Carpenter's Crew	18	16	14	12	8	6	4	2		
VI.		Sailmaker's Crew	2	2	2	2	1	1	1	1		
VI.		Cooper's Crew	2	2	2	2	1	1	1			
VI.		Able Seaman										
VI.		Yeoman of Store-room	The numbers included in these ratings are in									
VI.		Ordinary Seaman										
VII.		Cook's Mate										
VII.		Barber										
VII.		Purser's Steward in Vessels in which a Purser is allowed										
VII.		Captain's Steward										
VII.		Captain's Cook										
VII.		Ward or Gun-room Steward.										
VII.		Ward or Gun-room Cook										
VII.		Steward's Mate										
VII.		Landman										
							6	5	4	2	..	1
VIII.		Boy First Class	13	12	10	7	10	9	6	2	5	2
VIII.		Boy Second Class	18	17	16	11	3	2	1	1	1	..
		Total	211	194	174	131	111	91	68	50	37	21

			Making the total war complement of
First-rates	1st Class	529	900
	2d Class	479	850
	3d Class	429	800
Second-rates	1st Class	356	700
	2d Class	306	650
Third-rates	1st Class	351	650
	2d Class	301	600
Fourth-rates	1st Class	259	450
	2d Class	159	350
Fifth-rates	1st Class	139	300
	2d Class	119	280
Sixth-rates	1st Class	59	175
	2d Class	29	145
	3d Class	9	125
Sloops	1st Class	47	135
	2d Class	37	125
	3d Class	33	95
	4th Class	13	75
Bombs		16	67
Brigs, &c.	1st Class	27	60
	2d Class	17	50

Distribution of our Naval forces.

(73.) At the present time we have Admirals' flags flying at the Nore, Portsmouth, and Plymouth, in the Mediterranean, the West Indies, Halifax, and Newfoundland, in South America, the East Indies, Lisbon, Cape of Good Hope, and coast of Africa, and on particular service. In all ten Admirals.* These are the present Naval stations. In former Wars, much unpleasant litigation arose among the flag-officers of his Majesty's fleet, in consequence of the limits of the different stations not having been properly defined. Since that time, however, the Admiralty have so marked the boundaries of each command, that any future dispute seems impossible. These limits may be seen in vol. v. of Brenton's *Naval History*, p. 348, &c.

Admirals at present in the Navy List.

(74.) At the present time also there are on the Navy List one Admiral of the fleet, forty-six Admirals, fifty-five Vice-admirals, and sixty-four Rear-admirals.

Their rates of sea-pay and of half-pay *per diem* are the following:—

	Sea-pay.			Half-pay.		
Admiral of the fleet	£6	0	0	£3	3	0
Admiral	5	0	0	2	2	0
Vice-admiral	4	0	0	1	12	6
Rear-admiral or Commodore of the first class, Captain of the fleet	3	0	0	1	5	0*

Post Captains.

(75.) There are also 799 Post Captains, of whom fifty-four are actively employed. Their sea-pay is by the

* In 1812 we had two Admirals' flags flying in the Baltic, one at Leith, one at Yarmouth, four in the Texel and Scheldt, one at the Nore, one in the Downs, one at Portsmouth, one at Plymouth, one Guernsey and Jersey, one in Ireland, three in the Channel fleet; one on the coast of Portugal, seven in the Mediterranean, one at Newfoundland, one at Halifax, one at Jamaica, one at the Leeward Islands, one on the coast of Africa, two in South America, one at the Cape of Good Hope, and one in the East Indies: in all thirty-four.

The duties of a Commander in Chief are twofold—those relating to general service, and to the Civil establishments. They will be found in the Admiralty regulations and instructions and embrace a vast variety of important objects. Frequently a Commander in Chief has to undertake matters of a diplomatic nature, and sometimes he has to act on his own responsibility on circumstances of the greatest moment. This must of course be on foreign stations. The admirable letters of Lord Collingwood show his case with what ability he conducted some of the most delicate and important negotiations. In all the varied duties connected with his extensive command in the Mediterranean, after the Battle of Trafalgar, he showed himself a profound, and provident, and truly English-hearted statesman.

* In the reign of James II. Admirals and Captains of the Navy received only very small pay, but were allowed in addition a certain retinue, and for the men composing it so much a day, with the value of their provisions. Those allowances led to great abuses.

month, and is governed by the rate of the ship they command. A Captain of a first-rate in commission receives £61. 7*s*. 4*d*. per month, and the other rates, down to the fifth, diminish (omitting some trifling fractions) by a common decrement of an eighth part of that sum, thereby giving to the Captain of the last mentioned rate a monthly pay of £30. 13*s*. 8. The Captain of a sixth-rate receives a sixteenth part of £61. 7*s*. 4*d*. less than a Captain of a fifth-rate. It would be curious to know what circumstances led to the determination of these fractional decrements. A different scale of arrangement takes place in the pay of these officers when on half-pay. Each of the first hundred as they stand on the general list of officers in seniority receive 14*s*. 6*d*. a day; each of the next 150 a daily half-pay of 12*s*. 6*d*. and to the remainder 10*s*. 6*d*. per day.*

Commanders.

(76.) Of the Commanders there are 881, of whom 110 are employed on active service. The latter receive an eighth part of £61. 7*s*. 4*d*. (omitting a fraction) less than the Captain of a fifth-rate. Of this class of officers when on half-pay, each of the first 150 on the list receive 10*s*. a day, and the remainder 8*s*. 6*d*.†

By an Order in Council dated 22d February, 1693, the extravagant number of servants previously allowed was abolished, and the officers were allowed a number about equal to the present establishment. This wise and salutary plan, which excluded all profits on servants, and assigned an adequate rate of net pay, was, however, rescinded by Order in Council of 18th April, 1700, which established the following rates of pay, and reestablished the following extravagant number of servants:—

	Pay.			Servants.
Admiral of the fleet	£5	0	0	50
Admiral	3	10	0	30
Vice-admiral	2	10	0	20
Rear-admiral	1	15	0	15

and at these rates the pay of the flag-officers remained for upwards of 100 years. till, by Order in Council of 23d April, 1806, an alteration took place. It was computed in the Appendix to the Order in Council of February, 1693, that the annual saving to the Public on the reduction of the servants, would be on each officer as follows:—

Admiral of the fleet...............	£1014	0	0
Admiral..........................	557	14	0
Vice-admiral......................	304	4	0
Rear-admiral	177	9	0

* The Admiralty instructions to Captains respecting the fitting of ships, their stores and provisions, their books and accounts, their discipline, pilotage, and sick quarters, &c. &c. &c., form a body of knowledge of a most important kind; and we regret that our limits will only permit us thus briefly to allude to them.

† In every sea-port of France, the resort of ships of war, a Maritime Prefect is established, who is generally either a Vice or Rear-admiral. His functions correspond with those of a Port-admiral in England.

	Francs per ann.
The Maritime Prefects receive, when not employed at sea	18,000
Vice-admiral	15,000
Rear-admiral (Contre amiral).............	10,000
Post Captain (Capitaine de vaisseau, 1st class) .	5,000
Captain (Capitaine de vaisseau, 2d class)	4,500
Commander (Capitaine de frégate)	3,500.

When at sea, the officers receive a supplementary pay of one-fifth of the above, besides a daily mess allowance, which varies with the service or station on which they are employed.

The pay and allowances of officers as well as men, and also all payments whatever made on account of the service of the Navy, are subject to a deduction of three per cent. for the support of the sick, and for granting pensions to Naval invalids. There never has existed in France any special asylum for aged or invalid seamen, similar to Greenwich Hospital. It is true, however, Naval invalids, after thirty years' effective service, when supplied with certificates of good character, and supported by high interest, may be admitted into the *Hôtel des Invalides* at Paris; and it is also true that there are special Hospitals for the sick belonging to the Navy, while in service, at Brest, Toulon, Rochefort, L'Orient, and Cherbourg.

(77.) The rates of pay of Post Captains and Commanders for the different rates and sloops and bombs, may be represented by the following series, wherein p denotes the Captain's pay of a first-rate.

p...	Captain of a first-rate.
$\frac{7}{8}\,p$...	of a second-rate.
$\frac{6}{8}\,p$..	of a third-rate.
$\frac{5}{8}\,p$..	of a fourth-rate.
$\frac{4}{8}\,p$...	of a fifth-rate.
$\frac{7}{16}\,p$...	of a sixth-rate.
$\frac{3}{8}\,p$...	commander of sloops and bombs.

(78.) The Lieutenants amount to 3207; 658 of these being on active service. Lieutenants.

(79.) There are 496 Masters, of whom 98 are employed. Masters.

(80.) There are 12 Physicians belonging to the Navy, 712 Surgeons for service, and 318 Assistant Surgeons. 92 Surgeons and 108 Assistant Surgeons are on active service. Physicians. Surgeons.

(81.) The Pursers amount to 635, of whom 89 are on service. Pursers.

(82.) The active list of Chaplains amounts to 37. Chaplains.

(83.) As a proof, also, that the Admiralty are not unmindful of their important duties as regards the qualities of ships, and consequently their improvement, the following series of questions forms a part of the instructions issued to every officer on his taking the command of a ship.

day of 18 — A Report of the Sailing and other qualities of His Majesty's Ship , as found on strict observation thereof, between the of and this date.

		Feet.	Inches.
Her complement of men is			
Her light draught of water was stated to be	Forward...		
	Aft		
The draught of water which was estimated by the builder to be her best trim	Forward...		
	Aft		
The draught of water found, on trial, to be her best sailing trim, with three months' provisions and stores on board........................	Forward...		
	Aft		
The draught of water found, on trial, to be her best sailing trim, with as much provisions and stores on board as she can conveniently stow	Forward...		
	Aft.......		

		Tons.
The necessary quantity of iron ballast for her.......................		
The quantity of water she stows in her fore and main holds..............	In iron tanks	
	In casks ..	

			Feet.	Inches.
With three months' provisions and stores on board ..	Draught of water	Forward...		
		Aft		
	Height of ports .	Foremost .		
		Midships..		
		Aftermost .		
With as much provisions and stores on board as she can conveniently stow	Draught of water	Forward...		
		Aft.......		
	Height of ports .	Foremost .		
		Midships ..		
		Aftermost		

			No.	Pdrs.	Weight. Cwt.	Qrs.	Length. Ft.	In.
How armed.....	On lower deck .	Guns						
		Carronades						
	On middle deck.	Guns						
		Carronades						
	On main deck ..	Guns						
		Carronades						
	On quarterdeck	Guns						
		Carronades						
	On forecastle...	Guns						
		Carronades						
	On poop	Guns						
		Carronades						

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Character of the Ship after a trial of months.

- How many days of the following articles does she stow for her complement of men? .... Provisions. Bread .... Spirits ...
- Does she ride easy at her anchors? ....
- How many degrees does she heel, with a fresh breeze, under single-reefed top-sails and top-gallant sails? ....
- How many degrees does she heel, with a strong breeze, under double-reefed top-sails, without top-gallant sails?.........................
- How does she carry her lee-ports?...........
- Does she roll easy or uneasy in the trough of the sea? ....
- Does she pitch easy?.........................
- Is she, generally speaking, an easy or uneasy ship? ....
- How does she in general carry her helm? ... with all sails set?.......... / with treble-reefed top-sails and courses? ....
- How does she steer? ....
- How does she stay?.........................
- How does she wear? ....
- Is she weatherly or leewardly, compared with other ships?..........................
- How does she behave lying-to?...............
- She has run per hour by the log with as much wind as she could safely carry this sail to — Knots. Fathoms
  - Close-hauled with smooth water. Under whole or single-reefed top-sails and top-gallant sails .....
  - Close-hauled with smooth water. Under double-reefed top-sails....
  - Close-hauled with a head sea. Under double-reefed top-sails and top-gallant sails
  - Close-hauled with a head sea. Under close-reefed top-sails and courses ....
  - Large, under all sail that could with propriety be set ....
  - Before the wind under similar circumstances.................
- What is her best point of sailing compared with other ships?.....................
- Comparative rate of sailing compared with other ships?..............................
- Is she, generally speaking, a well-built and strong ship, or does she, on the contrary, show any symptoms of weakness?........
- Remarks, stating the grounds of such of the present answers as may differ from those of the last Report, and any other observations tending to form an accurate judgment on the qualities of the ship ....

Captain. Master. Carpenter.

There must therefore be an immense body of valuable knowledge now buried in the innumerable returns that have been made to these questions, and from which the hand of industry might deduce some important results.

Experimental squadrons.

(84.) Since the Peace, many keen and angry discussions have taken place respecting the best mode of building our ships of war; and several experimental squadrons have been sent out, composed of ships built by different projectors. Nothing decisive, however, seems to have resulted from these attempts; and Naval Architecture, considered as a Science, seems now to remain nearly as it did before. New plans have also been adopted for the internal fittings of our men of war; and in the case of the Thunderer, recently commissioned by the gallant Captain Wise, no cabins are permitted on the two gun-decks, the whole space being left free for fighting.

Appointment of a new Surveyor of the Navy.

(85.) The appointment of a new Surveyor of the Navy has led to the greatest changes in the forms and dimensions of ships hitherto attempted. The vessels in which Nelson and Duncan fought can hardly be compared with the magnificent vessels now building in our Dock-yards. The following Tables will furnish an account of their principal elements.

Dimensions of the new ships.

Dimensions.

Particulars.		London. 92Guns.	Castor. 36Guns.	Vernon. 50Guns.	Rover, Corv. 18Guns.	Snake, Brig. 16 Guns.
		Ft. In.	Ft. In	Ft. In.	Ft. In.	Ft. In.
Length of deck		205 6	159 0	176 0	113 0	100 0
Do. of keel for tonnage		170 4	133 $7\frac{3}{8}$	144 $6\frac{1}{4}$	90 1	76 $9\frac{1}{2}$
Breadth for ditto......		53 6	42 6	52 0	35 0	32 0
Extreme breadth		54 4	43 0	52 $8\frac{1}{2}$	35 4	32 4
Depth in hold		23 2	13 6	17 1	16 9	14 10
Burthen in tons....No.		2598	1283	2082	587	418
		Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
Calculated light water line	Forw.	15 2	12 8	....	9 5	8 14
	Aft..	18 3	15 6	....	12 3	12 0
Ascertained line when launched.	Forw.	....	12 8	13 6	....	8 1
	Aft..	....	15 2	17 6	....	12 4
Constructed load line	Forw.	23 3	19 1	20 9	14 0	13 6
	Aft..	24 3	20 1	21 9	15 0	14 9
Height of ports .	Fore.	8 2	8 8	10 6	7 0	6 3
	Mids.	7 0	7 8	9 0	6 0	5 3
	Aft..	8 2	8 6	9 9	6 2	5 4

Dimensions of their masts and yards

(86.) The next Table gives the dimensions of their masts and yards.

		London.			Castor.			Vernon.			Rover.			Snake.		
		Length.		Diameter.	Length.		Diameter.	Length.		Diameter.	Length.		Diameter.	Length.		Diameter.
		Yds.	In.	In.	Yds.	In.	In	Yds.	In	In.	Yds.	In.	In.	Yds.	In.	In.
Lower	Fore mast	36	28	$36\frac{1}{4}$	29	13	$27\frac{1}{4}$	35	7	36	22	8	21	22	8	21
	Main mast	39	32	40	32	0	$30\frac{1}{4}$	38	24	38	24	$4\frac{1}{2}$	23	24	9	23
	Mizen mast........	27	8	$21\frac{1}{2}$	23	2	20	27	9	24	19	20	17	....		....
	Bowsprit	25	1	$36\frac{7}{8}$	19	19	28	22	0	$34\frac{1}{8}$	14	31	21	14	12	23
Fore	Top mast..........	20	31	$20\frac{5}{8}$	17	0	$17\frac{3}{4}$	19	23	21	13	0	$12\frac{3}{4}$	14	6	13
	Top-gallant mast ..	10	12	$10\frac{3}{4}$	9	6	$9\frac{1}{4}$	8	15	11	6	12	$6\frac{1}{2}$	7	12	$7\frac{1}{2}$
	Lower yard	30	13	$21\frac{1}{2}$	25	6	$17\frac{1}{2}$	28	4	$21\frac{3}{4}$	17	30	15	18	6	$12\frac{1}{2}$
	Top-sail yard	21	18	$13\frac{3}{4}$	19	9	12	21	12	$13\frac{1}{2}$	14	15	9	14	18	9
	Top-gallant yard ..	14	8	$8\frac{5}{8}$	12	12	$7\frac{1}{4}$	13	12	$8\frac{1}{2}$	9	21	6	10	0	7
Main	Top mast..........	22	31	$20\frac{5}{8}$	19	6	$17\frac{3}{4}$	22	$1\frac{1}{2}$	21	14	27	$14\frac{1}{8}$	14	6	13
	Top-gallant mast ..	11	17	$11\frac{5}{8}$	10	9	$10\frac{1}{4}$	9	24	$11\frac{1}{2}$	7	6	$7\frac{3}{4}$	7	12	$7\frac{1}{2}$
	Lower yard	34	28	$24\frac{5}{8}$	28	26	$19\frac{7}{8}$	32	8	$22\frac{5}{8}$	20	24	$16\frac{1}{2}$	18	6	$12\frac{1}{2}$
	Top-sail yard	24	20	$15\frac{1}{2}$	21	20	$13\frac{3}{8}$	24	24	15	16	18	11	14	18	9
	Top gallant yard ..	16	9	10	14	20	$8\frac{3}{4}$	15	10	9	10	18	$6\frac{1}{2}$	10	0	7
Mizen	Top mast	16	17	$13\frac{3}{4}$	14	13	$11\frac{3}{4}$	16	10	$13\frac{1}{4}$	11	3	10	....		....
	Top-gallant mast ..	8	8	$8\frac{5}{8}$	7	24	$7\frac{5}{8}$	7	6	$8\frac{1}{8}$	7	6	$5\frac{1}{8}$	....		....
	Cross jack yard ...	24	20	$15\frac{1}{2}$	21	20	$13\frac{3}{4}$	23	18	15	16	18	11	....		....
	Top-sail yard	16	12	$10\frac{1}{8}$	14	20	$8\frac{3}{4}$	15	13	$9\frac{5}{8}$	11	18	6	....		....
	Top-gallant yard ..	12	3	$6\frac{1}{2}$	9	8	$5\frac{1}{8}$	17	21	$6\frac{5}{8}$	7	33	$4\frac{1}{2}$	....		....
	Driver boom	23	7	$13\frac{3}{4}$	19	19	$11\frac{5}{8}$	19	12	$12\frac{3}{4}$	12	24	10	19	0	$13\frac{1}{2}$
	Driver gaff........	17	6	$12\frac{5}{8}$	15	3	$10\frac{7}{8}$	16	$19\frac{1}{2}$	10	9	0	$7\frac{3}{4}$	12	12	10
	Jib boom	17	18	$15\frac{1}{4}$	15	0	$12\frac{5}{8}$	16	0	$15\frac{1}{2}$	11	0	10	10	0	$9\frac{1}{2}$
	Sprit-sail yard	21	18	$13\frac{3}{4}$	19	9	12	21	12	$13\frac{1}{2}$	14	15	11	14	18	9

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(87.) Such are the elements of some of the ships built or building in our Dock-yards, under the new state of things; and others on a still larger scale are spoken of. The Americans, acting on a principle of policy, taught us the necessity of augmenting the dimensions of our ships of war; and the vessels which our Dock-yards now produce, prove that the lesson has not been taught in vain. The increased expense arising from augmented dimensions, however, ought to render us cautious not to carry this principle beyond its necessary and proper limits.

Tactics. Undoubted claims of Clerk.

(88.) The great problem of breaking an enemy's line, owes its origin entirely to Mr. Clerk of Eldin. That splendid discovery ranks with many other great events which influence the fate of nations, and impart a new aspect to the affairs of men. By its ready and admirable adoption on the 12th of April, 1782, by Rodney, it led to the most decisive and brilliant results; and other commanders, following up the same great principle, have likewise gained from it an unfading renown. It must have been a source of the purest pleasure to Mr. Clerk, to have witnessed the complete success of the theory on which he had so long and so deeply meditated; and, moreover, to have received as its richest fruits, the public admission made of his transcendent merits, by the most illustrious commanders of his time. Within the last two or three years, however, a keen and bitter controversy has sprung up on the subject; and attempts have been made to dislodge Mr. Clerk from the high position to which public opinion had elevated him. The appearance of an eloquent and powerful Paper in the LIst volume of the *Edinburgh Review*,* embracing the whole scope and compass of the inquiry, has fortunately tended, in a high degree, to strengthen the entrenchments which time, and the unequivocal testimonies of the greatest minds, had raised up around him. Had Mr. Clerk been professionally connected with the Navy, so great a master of tactics, aided by all the results of a large experience, could not but have attained to its very highest honours. How often, in the history of knowledge, have great and important discoveries originated in quarters, from which they could have least been expected; and how rich and varied have been the benefits thus resulting to mankind!

Importance of tactics.

(89.) An attention to tactics cannot but be of the very first importance to a Naval commander. To neglect their cultivation is to give every advantage to the enemy, and to throw away that science which ought to be our guide. Our youngest seamen should be taught their rudiments, and a complete knowledge of them both in theory and practice should form a necessary part of Naval education. The subject is replete with the deepest interest in theory, and in its practice, is connected with the highest glory and renown. Naval tactics, it is true, have a limit in the possibilities of Navigation, and are, therefore, much less capable of variety of stratagem than the operations of armies; but, although the Naval warrior cannot place his fleet in ambush, nor at all times press the foe in his weakest part, it must not be thence inferred that there is no room left for the exercise of skill. The remark of Nelson just at the commencement of the splendid Battle of the Nile, "WHERE THERE IS SPACE FOR AN ENEMY'S SHIP TO SWING, THERE MUST BE ROOM FOR A BRITISH SHIP TO ANCHOR," proves that, in his case at least, the ready eye of genius was capable of seizing on whatever could contribute to glory and success. To devise and execute an unexpected manœuvre is, in fact, to secure the battle. This cannot be taught by books—the moment of invention is the moment of execution.

* Sir Howard Douglas has published a reply to this Article in a work entitled *Naval Evolutions*, London, 1832; but we are bound to say that it does not appear to us satisfactory.

Impressment.

(90.) On the important subject of impressment there has been much discussion during the Peace; but though the practice is so much condemned, no one has been able to suggest an adequate remedy. There can be no doubt that its employment is painful, and to be justified only by imperious circumstances. It is absolutely necessary, however, on the breaking out of a War, that the English fleet should be the first to get possession and command of the Channel; but how this can be done without the aid of impressment, has never been satisfactorily shown by those who contend for its entire abolition. It is an ancient prerogative of the Crown, on the maintenance of which mainly depends our Naval supremacy.

Stations of press-gangs.

(91.) According to Steel's *Lists*, the number of stations at which we had press-gangs during the late War varied from forty-five at the commencement, to thirty-four at the close of the War; and at these different stations there were employed from eighteen to twenty-five Captains, and from forty-seven to fifty-nine Lieutenants, with a number of men amounting on an average to not less than twenty at each station. It has been stated also, that during the late War there were never less than five line of battle ships, and sometimes eight, one 50-gun ship, three frigates, and five sloops, employed for the purpose of securing impressed men.

Small waste of life in the Naval service.

(92.) It is a circumstance most gratifying to record, that the waste of life in the trying and difficult enterprises of the past War, by no means amounted to what might have been anticipated. For example

There were on board the ships of war in all parts of the World, seamen and marines amounting,	Jan. 1, 1811, to 138,581.	whereof there died of disease, drowned, and killed in battle.	in 1810, 5183
	Jan. 1, 1812, to 136,778.		in 1811, 4265
	Jan. 1, 1813, to 138,324.		in 1812, 4211

The average of the crews being 137,894, and the average deaths, by disease, accident, and battle, 4,554, gives a rate of mortality of little more than one in $30\frac{1}{4}$;*

* Sussmilch, *Göttliche Ordnung*, vol. iii. p. 60. supposes the average measure of mortality for all Countries, taking town and villages together to be one in 36. According to Crome, the mortality in Silesia, from 1781 to 1784, was one in 30. In Guelderland, from 1776 to 1781, it was one in 27, and the same respectable authority states, that in the richest and most populous States of Europe, where the inhabitants of the towns are to the inhabitants of the country in so high a proportion as one to three, the mortality may be taken as one in 30. In several of the trades of the metropolis, the members of which, like the sailors, are between the ages of sixteen and sixty, the average mortality is greater than among seamen.

In the Naval instructions it is judiciously observed, that, "as cleanliness, dryness, and good air are essentially necessary to health, the Captain is to use his utmost endeavours to obtain these comforts for the ship's company as much as possible. The ship is always to be pumped dry; the pump-well is to be frequently swabbed, and a fire let down to dry it, (proper precautions being taken to guard against accidents;) and if the weather should prevent the lower deck ports from being opened for a considerable time, fires are to be made in the stoves, and by means of them and of wind sails the lower decks are to be kept as dry and as well ventilated as possible. The Captain is to be particularly attentive to the cleanliness of the men, who are to wash themselves frequently, and to change their linen twice every week. They are never to be suffered to sleep in wet clothes or wet beds, if it can possibly be prevented, and they

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a result of a very remarkable kind, when we consider the diversified circumstances of climate, and giving a happy close to a review of the gigantic growth of our Naval power.

Geographical position of England favourable to her Naval power.

(93.) The position of England at this moment in a Naval point of view is very remarkable. By her immense maritime superiority, she wields with ease the sceptre of the ocean. The fleets which may be preparing in the ports of those who look upon her Naval supremacy with jealousy and fear, are probably destined in future Wars to add to her own strength. Any idea of effecting a maritime coalition against her is destroyed, by her remarkable geographical position. *L'Angleterre*, says M. de Pradt,* *occupe une position centrale entre le Nord et le Midi de l'Europe; les escadres de ces deux divisions du Continent ne pourraient donc se réunir qu'à la portée des côtes de l'Angleterre et en passant sous ses canons; et ces escadres, quelles seraient-elles? Celles de la Russie? par où sortiraient-elles? A Héligoland, l'Angleterre ferme le passage du Sund; à Gibraltar, à Malte, elle intercepte tout ce qui navigue dans la Méditerranée, comme tout ce qui entre dans cette mer ou qui en sort. De Plymouth, elle bloque Cherbourg et Brest; ses côtes correspondent à celles de la Hollande, et, par ce rapprochement, la Belgique et la Hollande sont tenues en respect par la seule présence des ports Anglais: une coalition maritime contre l'Angleterre est donc matériellement impossible; moralement, elle l'est plus encore.*

Her fleets in future Wars can act in greater masses.

When France possessed Canada, Louisiana, the Antilles, and settlements in India, it might have distracted in some degree the fleets of the English; but now that the colonies of the French are so much reduced, the British fleets in future Wars will be enabled to act in greater masses than at any antecedent time. It hence becomes the policy of England, now that she has so triumphantly ascended to the very summit of maritime greatness, to consolidate her Naval power by every possible means.

Her immense Naval superiority.

Favoured by Nature in so many ways, she cannot but maintain her superiority if she be true to herself. "The vessels of a hundred different Countries wave their flags upon the Thames," says Dupin, and "nevertheless there the British flags alone surpass in number those of so many other nations. If the citizen of London is justly proud at the sight of so many fleets of merchant ships, daily arriving from the sea, or descending the river,—these, to export the products of the national industry, those, to import the produce and treasures of the most distant climes,—he cannot contemplate the busy activity that surrounds him, without feeling that he owes it all to the sovereignty of the sea. Nor are these evidences of unbounded and increasing wealth confined to the metropolis alone.

Her commerce.

He perceives Edinburgh on the shore of the most beautiful gulf of Scotland; Dublin on the spot most convenient for a rapid communication between London and Ireland; Quebec on the banks of the St. Lawrence; Calcutta on the borders of the Ganges; Halifax on the Northern coast of America; and the City of the Cape on the Southern extremity of Africa—the Cape of Storms,* which must be doubled in order to connect Europe with India;—in a word, in all parts of the World, the central points of the British power participate in the benefits of the commerce of the sea; and by these benefits contribute to the splendour, the wealth, and the power of the Country."

(94.) "In England, in Scotland, and in Ireland too, not only the Capitals just alluded to, but a multitude of cities of the first rank are built on the sea-coasts, or on the borders of large navigable rivers. Hence Liverpool, Bristol, Hull, Dundee, Aberdeen, and Glasgow, Belfast, Cork, and Waterford, become united by commerce with all the cities and all the manufactories of the interior; the interests of the maritime ports blending thus in harmony with all the great and transcendent interests of the Country. No other Country, also, is so wonderfully intersected with roads and canals; there being no point within the three Kingdoms, from which one may not, in four and twenty hours, arrive at one or other of the seas which surround them."

and Naval power mutually assist each other.

The commerce and Naval power of England hence mutually feed and protect each other. Commerce is at once the producer of wealth, and the constant, unwearied nursery of seamen; so that in the season of peace, the national enterprise is kept up, and a race of men are prepared by previous hardships, and by encountering Tropical whirlwinds and the icy seas of the Poles, to maintain the glory and renown of preceding wars.

Further steps to be made; our Dock-yards not perfect.

(95.) As the growth of our Naval power has been gradual, advancing by slow but certain steps from one condition of greatness to another, so has its administration on shore not been without obstacle and difficulty. Our Dock-yards, in no instance, present an example of an establishment that is perfect. It remains yet to be seen what a perfect Dock-yard should be; one that shall embrace magnificent basins, and be surrounded by spacious wharfs and quays; and have its most laborious duties performed by machines planned and executed by men capable of imparting to them the latest improvements in Mechanics. In former times, the various parts of the same Naval establishment were scattered; nor does the principle of concentration, so necessary for economizing time, and for uniting in a focus all the powers of a great department, seem ever to have been contemplated. Ships were built at one place, their victualling stores were received from another; their water at a third; their beer at a fourth, and their ordnance and powder

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are often, but particularly after bad weather, to shake their clothes and bedding in the air, and to expose them to the sun and wind."

The following Table, taken from James's *Naval History* of the five great Naval victories of the last War, of the numbers killed and wounded, proves that sea-fights are not nearly so destructive as land battles. In the single Battle of Talavera there were 4714 killed and wounded, being only 145 less than the whole number killed and wounded in the Naval battles alluded to. At Talavera, also, there were only 18,500 men engaged, whereas in the five Naval fights they amounted to upwards of 61,000.

Date of the Naval victory.	Name of the Admiral who commanded the fleet.	On board the fleet.	Number of men killed.	Number of men wounded.
June 1, 1794.	Earl Howe.	17,241	290	858
Feb. 14, 1797.	Earl St. Vincent.	9,900	73	227
Oct. 11, 1797.	Lord Duncan.	8,221	203	622
Aug. 1, 1798.	Lord Nelson.	7,401	218	678
Oct. 21, 1805.	Lord Nelson.	18,725	449	1241
	Totals ...	61,488	1233	3626
	Total killed and wounded..			4859

* *Appel à l'Attention de la France sur sa Marine Militaire par* M. de Pradt, *Ancien Archevêque de Malines*, Paris, 1832. *Certes*, says M. de Pradt, *les armées de l'Europe n'ont que trop su trouver le chemin de Paris; mais comment ses vaisseaux trouveraient-ils celui de Londres?*

* Cabo Tormentoso, so called by Bartholomew Diaz, a Portuguese. John I. of Portugal gave it the more inviting name of "The Cape of Good Hope."

Evils of a divided system.

from a fifth. Instead of one eye presiding over and controlling all the necessary elements for the speedy equipment of a numerous fleet, separate and sometimes conflicting interests were called into action; delays of messengers impeded the advancement of one ship, whilst currents and contrary winds, not then subdued by steam, occasioned stoppage in another. No wonder, in such a system of things, that our gallant seamen—a St. Vincent, or a Nelson,—sometimes in the ardour of their zeal, and impatient to meet the foe, bestowed words of bitter condemnation on our Dock-yards.

Those evils now under correction.

(96.) These evils, however, since the Peace, have gradually been under correction. In the two great Naval stations of Portsmouth and Plymouth, advantage has been taken of locality to bring the different departments more into union.

New Victualling establishment at Plymouth.

The Victualling Office at Plymouth, which a few years ago was placed in a narrow and inconvenient place remote from the Dock-yard, is now brought almost into juxta-position with it, forming the Eastern side of the beautiful natural basin of Hamoaze, whilst the Dock-yard and gun-wharf form the Northern. Here, in this new creation of the Rennies, is to be found every thing requisite for the victualling of a fleet. Ample storehouses, corn-mills, and bakehouses of enlarged dimensions,* slaughter-houses, cooperages, brewhouses, all under the eye of an intelligent and active superintendent,* cannot but produce, aided as it must be by the application of steam to Naval power, the most astonishing results.† Other improvements will doubtless take place in the Dock-yards themselves; machinery will be more extensively employed; railways will be laid down; Science will gain a greater ascendency; the true principles of labour will be better understood; and thus by one improvement added to another, and a rigid economy in all the departments of the State, the Naval power of England shall rise higher and higher in the scale of greatness, maintaining her transcendent superiority in spite of all the rivals who endeavour to pull her down.

Equidistant Ordinates.

Equidistant ordinates.

(97.) Ships disclose a variety of parts whose solidities and surfaces require to be computed with precision and care, but whose mixed and uncertain forms can only be reached by approximation. If we take by way of examples the surface of the water section, the figure of the immersed volume, the portions of the vessel plunged at times beneath the sea in the acts of rolling and pitching, or raised above the waves by their buoyant power, we shall find forms both of a solid and superficial kind, incapable of reduction to any regular figure.

Methods of computing irregular figures.

(98.) Various methods have been devised by Mathematicians for computing the areas and solidities of figures of this kind, by the aid of equidistant ordinates referred to a common axis. These modes of calculation are found to approximate with more or less certainty to the desired end; and much of the accuracy, whatever rule be employed, will depend on the increased number of the ordinates themselves.

Two rules commonly employed.

(99.) There are two rules commonly employed in these kinds of calculation, distinguished for their simplicity and accuracy. The first may be exhibited under the form of $(\Sigma + 4\,S + 2\,s)\,\dfrac{i}{3}$,

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* Until within the last few years, all the flour and biscuit consumed in the Navy was furnished by private contract. The most flagrant impositions and frauds were but too generally the consequence of this mode of supply, in defiance of all the vigilance of the heads of departments. The flour and biscuit were stipulated to be of the second best quality; but instead of this, the former was generally mouldy, damaged, or of a very inferior description to that bargained for; while the latter was usually compounded of bad flour, bean meal, old worm-eaten biscuits ground down, and various other cheap or unwholesome materials. To obviate these frauds, Government, a few years ago, erected steam-mills at Deptford and Portsmouth, for the purpose of grinding flour for the Navy; and a very superior and cheaper article being the result, it was determined, in addition to grinding the flour, to attempt also the manufacture of biscuit from it, at these establishments. The impossibility of accommodating and effectually superintending the multitude of bakers required to knead the dough in the usual way, by hand, so as to effect the supplying of the whole Navy, would have rendered this praiseworthy effort, in a great measure, abortive, had not the ingenuity of Mr. Grant, storekeeper at Portsmouth, obviated the difficulty. By the attachment of a few simple pieces of machinery to the engine driving the flour-mill, the dough is now worked, rolled out, and stamped into biscuits, with an expedition inconceivable, and with a saving of two-thirds of the number of bakers required to perform these processes by hand. The flour and water are first put into a trough, through which passes an iron spindle, armed with eighteen knives, in two rows, *i. e.* nine in each row, on opposite sides of the spindle. A strap connected with the engine turns the spindle round, and by means of the revolving knives, the flour and water are in a few minutes worked into dough fit for being stamped into biscuits. The dough is now taken piecemeal from the trough, and shaped by hand into longish rolls upon two movable baking-boards, supported by small iron pillars, having castor wheels at the top: these pillars are in three rows, extending from the trough to the two rolling machines; and along the castors upon their tops the baking-boards are pushed by hand, towards the rollers, under which the dough is rolled out into thin cakes, by their backward and forward swinging motion. The baking boards are now pushed out by hand from under the rollers, and slided along three other rows of pillars, connecting the two rollers with the two cutting machines, each containing forty-two hexagonal dies, under which they are momentarily placed, and eighty-four biscuits are thus cut out by a single stamp of the two machines. The kneading, rolling, and stamping portions of the machinery being separate, can consequently be put in separate motion or at rest at the will of the baker. By the machinery at Portsmouth, under Mr. Grant's superintendence, 160,000 pounds of biscuit can be manufactured in twenty-four hours; constituting a day's ration for the crews of twenty sail of the line; and with eight or ten such pieces of machinery, biscuit rations may be daily manufactured for 160,000 men, being the greatest number of seamen and marines employed during the hottest period of the late War. The biscuit is free from flintiness, and in every respect more palatable than that made by hand, in consequence of being more thoroughly kneaded. From the rapidity of the manufacture, also, no more biscuit need now be baked than is required for immediate use, from the supply by this process being as certain as it is rapid, so that our seamen will always in future have fresh-baked and wholesome biscuit served out to them, even on foreign stations, instead of the stale, mouldy, worm-eaten, and unpalatable contract trash generally furnished during the War, which had often been baked for years before issued. It is only those who have been doomed to the penance of the contract flour and biscuit that can duly appreciate the great boon conferred on our brave seamen by this project of the Government; the above articles now supplied to the Navy being very superior in quality to those furnished for the merchant service—such, indeed, as are fitting for any gentleman's table; and all this at a much lower cost than the former contract supplies.

In addition to the usual King's mark of the broad arrow, the word "Machinery" is stamped upon the biscuits By the Naval estimates for the years 1833-34, it appears that Mr. Grant has received the sum of £2000 for his ingenious invention.

* Captain Phipps Hornby, R.N. C.B., one of the gallant heroes who commanded in the famous action off Lissa, 13th March, 1811.

† Frequently during the last War, and doubtless in all preceding Wars, ships were wind bound for a considerable time in the harbour of Hamoaze, entirely ready for sea, commanded by an ardent Captain, but unable to move. Now, the moment a ship is ready, a steamer can take her down the harbour, and, if necessary, carry her at once out to sea. Not long before this note was written, its writer saw the Caledonia, a first-rate of 120 guns, taken down by two little steamers, one lashed on her larboard bow and the other on her starboard quarter. The great ship was moving without a sail, her numerous crew were motionless, enjoying the scene. It seemed like two infants bearing a giant to some great labour.

where Σ represents the sum of the extreme coordinates, S the sum of all the *even* ordinates, s that of the *odd* ordinates, and i the common interval between the ordinates. In this rule it is essential that the uniform *laminæ*, into which the area or solidity be divided by the equidistant ordinates, should, whether those ordinates be lines or areas, be in all cases an *odd* number. This rule is founded on the supposition that each portion of the curve passing through the extremities of three successive ordinates, is a portion of a conic parabola; and hence the error arising from its general application will only be the spaces intercepted between such parabolic segments and the given curve.

(100.) Another rule was brought into practice by Atwood, wherein he supposed arcs of a cubic parabola to pass through every four successive ordinates, the number of ordinates being a multiple of 3 + 1. This rule he exhibited under the form of

$$(\mathrm{S} + 2\,\mathrm{P} + 3\,\mathrm{Q})\,\frac{3\,i}{8},$$

wherein S represents the sum of the first and last ordinates, P the sum of the 4th, 7th, 10th, &c. ordinates, Q that of the 2d, 3d, 5th, 6th, 8th, 9th, &c. ordinates, and i the common interval among them.

(101.) In the application of either of these rules to the important objects before us, care must be taken that the ordinates be sufficiently multiplied as to admit of no sudden transitions in their lengths. Should such an instance occur, and it may do so in the practice of Naval Architecture, a new abscissa should be adopted, to embrace, with the aid of new ordinates applied to *it*, the areas or solidities of such irregular parts.

The Displacement.

The displacement

(102.) It is a maxim in Hydrostatics that any floating body, whatever be its dimensions and form, will always displace a volume of the fluid in which it is immersed, exactly equivalent to the weight of the body; and the truth of the principle will be evident when we consider that the upward vertical pressure of the fluid supporting the body is exerted in precisely the same way, whether it acts on the body or on the volume of fluid previously displaced. To discover the total weight of a ship, therefore, it is only necessary to ascertain the weight of water she displaces when she floats in equilibrium; the question hence becomes one of ordinary mensuration. to find the number of cubic feet contained in the body below the plane of flotation, having its figure and necessary dimensions given.

varies between the limits of the light and load water lines.

(103.) The displacement of a ship is, however, a variable quantity contained between the limits of the light and load water lines, the first representing its minimum state, or the weight of the hull just as she is launched, and the second its maximum condition, when the vessel has received her masts and yards, her rigging, sails, ballast, water, provisions, and men, guns, powder, shot, boatswain's and carpenter's stores, &c., and in fact, all that she may require to fit her for the great purposes of war. Between these two limits, therefore, there may be every imaginable variety of displacement, and hence it is not unusual to estimate the displacement even of a single inch, both at the light and load water lines.

No invariable relation between the light and load displacements.

(104.) There seems to be no fixed and invariable relation between the light and load displacements, even in ships of the same class; and among different classes the differences are very remarkable, though here and there coincidences may be met with worthy of attention, but which, nevertheless, seem more the result of accident than of any settled design.

Displacements of several classes of ships.

(105.) In the following Table we have given the displacements of several classes of ships, derived from Mr. Edye's excellent *Naval Calculations;* and in order more clearly to show the relation of the two, we have introduced the actual light and load displacements in the first and second columns, representing the former by the constant quantity, 100, in the third column, and placing in the fourth, the proportional numbers for the corresponding displacements at the load water line.

Relations between particular ships.

(106.) Among some of these ships there exists a relation worth adverting to. The 120 and 92-gun ships, for example, are both related as 100 : 187; the 80-gun ship and the small vessel, the Rover, as well as the razée 26, and the 10-gun brig, and between one or two others there exists a close approximation. The greatest difference in the two displacements exists in the 52-gun ships, and the least in the razée of 50. The contrast between these two vessels, considering how small is the difference in their fighting forces, is very remarkable, and shows what immense powers of capacity and stowage a skilful architect may impart to his vessel, while he preserves unimpaired her fighting powers.

Rate of Ship.		Light Displacement in Feet.	Load Displacement in Feet.	Proportional Numbers.	
First....	120	86,098	160,614	100	187
	80	65,296	124,977	100	191
	74	56,287	104,920	100	186
Razée	50	50,673	87,154	100	172
	52	36,071	75,420	100	209
	46	26,725	50,755	100	190
	26	24,430	41,805	100	183
	28	13,568	27,277	100	201
Corvette.	18	10,344	21,371	100	207
Gun-brig	18	8,068	16,035	100	199
	10	5,693	10,404	100	183
Schooner		3,983	7,338	100	184
Cutter		2,835	5 725	100	202
CLASS OF NEW SHIPS.					
London ...92		77,420	144,532	100	187
Castor 36		33,026	63,861	100	193
Vernon....50		48,510	89,747	100	185
Rover 18		10,430	19,899	100	191
Snake 16		8,050	15,234	100	189

Proportional displacements of the several rates.

(107.) The proportional relations of the load displacements of different classes of ships are given in the next Table, adopting 1000 as the representative of a ship of the first class of 120 guns.

	Rate of Ship.	Proportional Numbers for the Displacement.
	120	1000
	80	778
	74	653
Razée	50	543
	52	470
	46	316
	26	279
	28	170
Corvette........	18	133
Gun-brig	18	99
	10	65
Schooner		46
Cutter		36

Naval Architecture.

New Class of Ships.

London	92	890
Castor	36	398
Vernon	50	559
Rover, corvette .	18	124
Snake, brig.....	16	95

Importance of the displacement.

(108.) To determine the displacement of a ship is a great and important problem. The forms of ships already constructed very frequently guide the Naval Architect in estimating the displacement of a new vessel; but cases may arise wherein he may feel disposed to have recourse to first principles, and reascending to the elements of his Art, to compute from the dimensions and specific gravities of the different materials to be employed in composing his vessel, her complement of men, her guns, the vast variety of her stores, and the absolute amount of her weight. This it will be obvious must be a laborious process, and requiring immense processes of calculation; but such obstacles will have little influence with him who is destined to extend the boundaries of the Art.

How it is applied.

(109.) Having, however, this weight, whether derived from former vessels, or by the method last adverted to, the Naval Architect will proceed to assign to it a displacement capable of giving him the stowage, the velocity, and the qualities necessary for fighting with ease and security her guns, even in a troubled sea. It would appear as if this latter element has in very many cases been singularly neglected, and that the lower deck ports have been so near the water as to afford room for great apprehension, or at least to impair the fighting powers of the ship, by the necessity that existed of frequently closing them. Among the ships now actually existing in our fleets, the height of the midship ports of a first-rate of 120 guns appears to be but 5 feet 6 inches, and of a 74, but 5 feet 8 inches above the water; whereas in the new class of the London of 92 guns the midship ports will be elevated 7 feet, and in the Vernon 9 feet. So the old corvette of 18, which had her midship ports only 4 feet 11 inches above water, in the Rover will have them 6 feet.*

* The height of the midship ports is from the circumstances of construction at a minimum elevation above the water, the fore and after ports being much higher. In the second column of the annexed Table we have the excess of the height of the fore ports above the midship ports; and in the succeeding column the height of the after ports above the same.

Class of Ships.		Excess of Height of Fore Ports above Midship Ports.		Excess of Height of After Ports above Midship Ports.	
		Ft.	In.	Ft.	In.
	120	1	4	1	0
	80	2	9	0	10
	74	1	10	0	1
Razée.......	50	1	0	0	1
	52	1	2	1	0
	46	0	10	0	10
Razée.......	26	0	11	1	5
	28	0	3	0	6
Corvette.....	18	0	8	0	11
Gun-brig....	18	0	8	1	1
	10	0	5	0	4
Schooner		1	2	0	2
Cutter		2	7	0	9
New Class.					
London	92	1	2	1	2
Castor......	36	1	0	0	10
Vernon......	50	1	6	0	9
Rover corvette	18	1	0	0	2
Snake brig ..	16	1	0	0	1

Importance of attending to it.

This is so important a consideration, and the mode of computing the necessary displacement corresponding to a given weight, is now so completely understood, that it would be unpardonable in the present state of our knowledge, to construct any ship without a due attention to so important a principle. It is proper to give a ship the requisite stability with as little ballast as possible, which will enable the constructor to reduce the displacement, and may facilitate the sailing and working of the vessel. Hence every weight introduced into a vessel should be kept as low as possible. In the case of a merchant-ship it is manifest that if the weight of the hull, rigging, and necessary stores be known, and the amount of displacement also, the weight of her cargo may hence be determined.

Approximation of Bouguer.

(110.) Bouguer, whose mind seems to have been directed in so many ways to simplify all the processes of computation in Naval Architecture, imagined that a close approximation to the displacement might be obtained by considering the ship's body *a semi-spheroid*, to which perhaps it assimilates more closely than to any other body. The content of a spheroid being $\frac{11}{21}$ of its circumscribing parallelopiped, he supposed the displacement might be obtained by estimating the same fractional part of the rectangular solid contained by the three principal dimensions of the ship at the water's surface. In the case of sharp ships, he modified the fraction to $\frac{11}{28}$, but it would seem that the results give considerably less than the true displacement.

More accurate methods now necessary.

(111.) The state of Naval Architecture at the present time, however, requires the application of more accurate rules. We have already alluded to formulæ, which, applied to a body like a ship, are capable of affording the solidity of the whole or any part of it immersed; and so accurate are the practical modes now adopted by the ship-builder, that the error in the total weight of a ship of 3000 or 4000 tons, is often less than half a ton. The finding the displacement of a ship is, however, only an ordinary problem in mensuration, and to a geometrician cannot present the smallest difficulty.

Sheer and body plans necessary to find the displacement.

(112.) The sheer and body plans are necessary, in order to find the displacement. Suppose A B C D, plate i. fig. 1, to represent the sheer draught of a ship, and W w the load water line for which the displacement is to be calculated. In this line take two points, E and F, each within a few feet of the stem and stern; and let the interval E F be divided into such a number of equal parts, that the number of points of division, together with the extreme points E and F, may either be represented by an odd number, or be a multiple of $3+1$. Through these points, let perpendiculars, 1, 1; 2, 2; 3, 3 .... 26, 26; 27, 27; 28, 28; be drawn to the water line, and the vessel will be divided into vertical laminæ, of equal thickness. Moreover, let O P Q, fig. 2, represent the body plan of the same ship, the lines 1, 1; 2, 2; 3, 3; 4, 4; &c. representing transverse vertical sections extending to the outside of the ship, at the several stations 1, 2, 3, 4, &c. in the sheer draught, fig. 1; those on the right hand, being the vertical sections *before* the midship section, and those on the left, the vertical sections *abaft* the same section. Moreover, below the load water line W w, let several horizontal

There are only two differences in the Table, it will be remarked, which are equal, namely, the Razée 46, and the London 92 guns.

lines, 22, 33, 44, &c. be drawn parallel to it, at some constant distance, suppose a foot from each other, both in the sheer and body plans. These sections will divide the body of the ship into horizontal laminæ of uniform thickness. Sometimes, however, the thickness of the horizontal sections in the upper body exceed those in the lower body, the form of the ship requiring the horizontal sections to be increased in the latter. If now the half breadths on the several horizontal lines of the sections in the body plan be carefully measured, by means of the scale of the drawing, the numerical results will be found as in the annexed Table. These half-breadths may also be found by means of fig. 3.

Table of Ordinates.—Vertical Sections of Middle Body. Common interval 6 feet.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	16.05	19.31	21.33	22.7	23.6	24.13	24.48	21 72	24.85	24.9	24.9	24.9	24.9	24.9	1
2	10.73	14.88	17.91	20.24	22.00	23.21	23.96	21.44	24.73	24 93	24.95	25.00	25.00	25.00	2
3	6.5	10.12	13.33	16.10	18.46	20.26	21.6	22.55	23.24	23.72	24.04	24.25	24.44	24.65	3
4	3.88	6.34	9.06	11.82	14.32	16.44	18.17	19.5	20.5	21.35	22.00	22.38	22.77	22.9	4
5	2.35	3.83	5.71	7.86	10.17	12.28	14.14	15.64	16.92	17.95	18.8	19.43	19.9	20.21	5
	89.84	128.26	161.58	191.00	215.97	235.53	250.34	261.22	269.17	275.41	279.58	282.35	284.76	286.01	
	15	**16 ⊕**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	
1	24.9	24.9	24.9	21.85	24.84	24.83	24.76	24.7	24.53	24.23	23.72	22.87	21.18	18.55	1
2	25.00	25.00	25.00	25.00	25.00	24.9	24.86	24.53	21.05	23.36	22.42	21.01	18.83	15.00	2
3	24.65	24.65	24.65	24.51	24.34	24.06	23.52	23.08	22.32	21.34	20.03	18.14	15.29	11.14	3
4	23.04	23.08	23.00	22.78	22.53	22.1	21.44	20.62	19.58	18.32	16.63	14.36	11.54	7.65	4
5	20.38	20.39	20.25	19.96	19.56	18.8	18.17	17.2	15.96	14.41	12.55	10.25	7.56	4.54	5
	286.74	286.91	286.45	284.95	283.20	279.75	275.17	268.66	259.65	248.04	232.53	210.88	189.00	135.87	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	2.35	3.83	5.71	7.86	10.17	12.28	14.14	15.64	16.92	17.95	18.8	19.43	19.9	20.21	1
2	2.13	3.38	5.06	7.00	9.12	11.23	13.04	11.54	15.85	16.98	17.84	18.55	19.0	19.23	2
3	1.95	2.96	4.45	6.19	8.12	10.15	11.89	13.44	14.8	15.9	16.74	17.5	17.91	18.27	3
4	1.72	2.64	3.96	5.5	7.24	9.16	10.83	12.4	13.68	14.32	15.68	16.52	16.95	17.3	4
5	1.51	2.26	3.38	4.72	6.21	7.92	9.54	11.07	12.38	13 5	14.42	15.24	15.71	16.1	5
6	1.33	1.95	2.91	4.03	5.31	6.8	8.26	9 78	11.0	12.2	13.2	13.85	14.35	14.8	6
7	1.18	1.72	2.47	3.41	4.43	5.67	6.96	8.21	9.44	10.55	11.35	12.05	12.6	13.04	7
8	1.01	1.48	2.08	2.81	3.52	4.54	5.57	6.47	7.45	8.2	8.75	9.43	9.9	9.9	8
9	.9	1.26	1.68	2.22	2.68	3.32	4.01	4.4	4.7	4.7	4.7	4.7	4.7	4.7	9
10	.8	1.15	1.32	1.67	1.92	2.24	2.60	2.72	2.85	2.85	2.85	2.85	2.85	2.85	10
11	.72	.81	1.00	1.2	1.28	1.42	1.58	1.62	1.62	1.62	1.62	1.62	1.62	1.62	11
	10.55	15.86	22.99	31.56	40.7	50.92	60.43	68.78	76.12	82.26	86.78	91.2	93.9	95.59	
	1.33	1.39	1.46	1.55	1.58	1.64	1.72	2.15	2.19	2.20	2.21	2.22	2.23	2.23	
	101.72	145.51	186.03	224.11	258.25	288.09	312.49	332.15	347.48	359.87	368.57	375.77	380.89	383.83	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	
	15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	
1	20.38	20.39	20.25	19.96	19.56	18.8	18.17	17.2	15.96	14.41	12.55	10.25	7.56	4.54	1
2	19.48	19.5	19.28	19.02	18.58	18.0	17.13	16.13	14.9	13.25	11.35	9.1	6.37	3.78	2
3	18.51	18.54	18.38	18.08	17.62	17.0	16.12	15.04	13.81	12.15	10.23	7.95	5.53	3.16	3
4	17.60	17.64	17.45	17.15	16.65	15.98	15.08	13.96	12.72	11.1	9.15	7.0	4.77	2.63	4
5	16.38	16.42	16.23	15.38	15.35	14.64	13.74	12.6	11.35	9.72	7.88	5.94	3.95	2.08	5
6	14.88	14.95	14.75	14.32	13.8	13.08	12.16	11.07	9.86	8.24	6.52	4.91	3.2	1.56	6
7	13.04	13.21	12.9	12.28	11.77	11.14	10.2	9.3	8.14	6.74	5.4	4.04	2.56	1.15	7
8	9.9	9.9	9.7	9.3	8.68	7.9	7.17	6.63	5.95	5.1	4.25	3.16	2.0	.78	8
9	4.7	4.7	4.7	4.7	4.7	4.63	4.5	4.24	3.93	3.58	3.16	2.35	1.48		9
10	2.85	2.85	2.85	2.85	2.85	2.8	2.7	2.6	2.44	2.27	2.08	1.58	1.00		10
11	1.62	1.62	1.62	1.62	1.62	1.5	1.46	1.4	1.3	1.23	1.14	.93			11
	96.52	96.79	95.6	93.25	90.57	86.56	81.42	75.63	68.8	59.96	50.1	38.93	25.5	12.73	
	2.23	2.23	1.99	1.96	1.92	1.87	1.83	1.78	1.72	1.67	1.62	1.5	1.61	2.92	
	385.49	385.93	384.04	380.18	375.69	368.18	358.42	346.07	330.17	309.67	284.25	251.31	207.11	151.52	
	15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	

Naval Architecture.

Of After Body. *Common interval* 1.83 *feet.* *Of Fore Body.* *Common interval* 3 *feet.*

Upper Body. Horizontal Sections 3 feet apart.

Pieces aft including Post and Rudder	7	6	5	4	3	2	1			Middle areas.	1	2	3	4	5	Pieces forward including the knee of head.	Whole half horizontal areas.
109.72	.8	3.8	7.51	10.6	12.87	14.69	16.05	1	1	3856.38	18.55	16.4	13.30	8.72	.8	149.06	4115.17
67.95	..	2.13	4.0	5.81	7.53	9.25	10.73	2	2	3713.13	15.00	12.54	9.2	4.84	..	103.67	3884.75
41.36	..	1.43	2.34	3.32	4.42	5.44	6.5	3	3	3401.77	11.14	8.7	5.72	2.22	..	67.21	3510.34
26.93	..	.9	1.43	2.00	2.55	3.24	3.88	4	4	2962.51	7.65	5.42	3.12	..	..	39.30	3028.73
19.00	..	.74	1.02	1.32	1.62	2.0	2.35	5	5	2412.40	4.54	2.9	1.36	..	..	19.27	2150.67
Areas from ord. 1 to ord. 5.	..	19.52	34.85	49.80	63.65	77.53	89.84			..	135.87	108.54	75.43	30.30	..	..	..

Lower Body. Horizontal Sections 0.75 feet apart.

	7	6	5	4	3	2	1				1	2	3	4	5		
19.00	..	.74	1.02	1.32	1.62	2.0	2.35	1	1	2412.40	4.54	2.9	1.36	..	..	19.27	2450.67
17.77	..	.73	.97	1.23	1.45	1.76	2.13	2	2	2256.88	3.78	2.38	.87	..	..	16.27	2290.92
15.91	..	.68	.92	1.13	1.3	1.55	1.95	3	3	2100.80	3.16	1.89	..	..	..	12.26	2128.97
15.46	..	.67	.87	1.04	1.18	1.43	1.72	4	4	1952.41	2.63	1.5	..	..	..	9.74	1977.61
13.55	..	.62	.8	.97	1.08	1.28	1.51	5	5	1763.44	2.08	1.1	..	..	..	6.98	1783.96
13.17	..	.62	.75	.87	.97	1.13	1.33	6	6	1571.87	1.56	.74	..	..	..	6.68	1591.72
13.53	..	.6	.72	.82	.89	1.00	1.18	7	7	1337.98	1.15	..	..	..	..	5.13	1356.64
12.08	..	.58	.67	.74	.82	.92	1.04	8	8	1016.86	.78	..	..	..	..	4.6	1033.54
10.91	..	.57	.63	.65	.75	.8	.9	9	9	593.80	..	..	..	..	..	11.08	615.79
10.7	..	.55	.58	.64	.68	.75	.8	10	10	374.48	..	..	..	..	..	7.81	392.99
10.31	..	.55	.58	.6	.62	.65	.72	11	11	213.74	..	..	..	..	..	11.60	235.65
Areas from ord. 5 or 1 to ord. 11	..	4.7	5.77	6.78	7.67	8.96	10.55			..	12.73	6.51	.83	..	..	..	..
Pieces below including the keel and false keel.	15.71	1.28	1.29	1.3	1.31	1.32	1.33			..	2.92	3.36	3.5	7.07	4.96	..	..
Whole half areas of the vertical sections.	15.71	15.66	41.94	57.88	72.63	87.81	101.72			..	151.52	118.41	79.76	37.97	4.96	..	..

Dimensions of preceding Table enable us to find the displacement both by vertical and horizontal sections.

(113.) The dimensions contained in the preceding Table will enable us to obtain the displacement, both by the vertical and horizontal sections into which the ship has been divided. If we adopt, in the first place, the vertical sections, the area of each must be found between the load water line W w, and the lowest horizontal line which has been drawn, by means of one of the formulæ before given; and to this must be added the small areas below the last-mentioned line, consisting of the remaining curvilineal areas of the section, together with the areas of the sections of the keel and false keel. These results will enable us to obtain the entire half areas of all the vertical sections from E to F. If now either of the formulæ be applied to the successive areas, the half displacement will be found between the foremost vertical section F f, and the aftermost E e. The solids *before* the section F f, and *abaft* the section E e, are then to be separately computed by applying one of the formulæ to the small horizontal areas at the extremities. These three solids added together will give the half displacement by means of the vertical sections.

Vertical sections.

Example of one vertical section.

(114.) To give an example of the mode of computing one of these vertical sections, we take the main section $\frac{16}{\phi}$. This section, in common with all the others, it has been found convenient to divide into two portions, denominated the *upper* and *lower* spaces, for the purpose of ensuring greater accuracy in the computations, the horizontal sections being estimated at the interval of one foot for the former, and 0.25 feet for the latter. We shall apply to these spaces the first formula.

UPPER SPACE.

Extreme Ordinates.	Even Ordinates.	Odd Ordinates.
1....24.9	2....25.00	3....24.65
5....20.39	4....23.08	2
45.29 = Σ	48.08	49.30 = 2 S
	4	
	192.32 = 4 S	

and since $\frac{i}{3} = 1$, we shall have

$$(\Sigma + 4\,S + 2\,s)\ \frac{i}{3} = (45.29 + 192.32 + 49.3) \times 1$$
$$= 286.91,$$

which is the semi area of the upper portion of the main section.

LOWER SPACE.

Extreme Ordinates.	Even Ordinates.	Odd Ordinates.
1...20.39	2...19.50	3...18.54
11... 1.62	4...17.64	5...16.42
22.01 = Σ	6...14.95	7...13.24
	8... 9.90	9... 4.70
	10... 2.85	52.90
	64.84	2
	4	105.80 = 2 s
	259.36 = 4 S	

and since $\frac{i}{3} = \frac{1}{4}$, we shall have

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3} = (22.01 + 259.36 + 105.8) \times \frac{1}{4} = 96.79,$$

which is the semi area of the lower portion of the main section.

Hence the entire semi area of the main section will consist of the

Semi area of the upper space	=	286.91
Semi area of the lower space....	=	96.79
Semi area to the keel	=	0.79
Semi area of the section of the keel	=	1.44
Semi area of the main section....	=	385.93

(115.) In this manner may the semi areas of all the vertical sections be obtained, the successive results of which are entered in the lowest horizontal line of the Table.

(116.) To apply these semi areas for the purpose of finding the displacement, it may be remarked, in the first place, that the ship being divided transversely into three portions, denominated the *middle body*, the *after body*, and the *fore body*, the solidity of each must be computed.

MIDDLE BODY, *or part comprised between the vertical sections* E *e*, F *f*.

The solidity of the middle body we purpose calculating by means of the formula

$$(S + 2\,P + 3\,Q)\,\frac{3\,i}{8}.$$

Extreme Areas.	Second Class of Areas.	Third Class of Areas.
1..101.72	4..224.11	2..145.51
28..151.52	7..312.49	3..186.03
253.24 = S	10..359.87	5..258.25
	13..380.89	6..288.09
	16..385.93	8..332.15
	19..375.69	9..347.48
	22..346.07	11 .368.57
	25..284.25	12..375.77
	2669.30	14..383.83
	2	15..385.49
		17..384.04
	5338.60 = 2 P	18..380.16
		20..368.18
		21..358.42
		23..330.17
		24..309.67
		26..251.31
		27..207.11
		5660.23
		3
		16980.69 = 3 Q

and since $\frac{3\,i}{8} = 2.25$, we shall have

$$(S + 2\,P + 3\,Q)\,\frac{3\,i}{8} = (253.24 + 5338.6 + 16980.69) \times 2.25 = 50788.1925,$$

which is the half displacement of the *middle body*.

FORE BODY, *or part before the vertical section* F *f*.

We shall compute this by the same formula.

Extreme Areas.	Even Areas.	Odd Areas.
1...151.52	2...118.41	3...79.76
5... 4.96	4... 37.97	2
156.48 = Σ	156.38	159.52 = 2 s
	4	
	625.52 = 4 S	

and since $\frac{i}{3} = 1$, we shall have

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3} = (156.48 + 625.52 + 159.52) \times 1 = 941.52,$$

which is the half displacement of the *fore* body.

AFTER BODY, *or part abaft the vertical section* E *e*.

This we shall compute by means of the formula

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3}.$$

Extreme Areas.	Even Areas.	Odd Areas.
1... 101.72	2...87.81	3...72.63
7... 15.71	4...57.88	5...41.94
117.43 = Σ	6...25.50	114.57
	171.19	2
	4	229.14 = 2 s
	684.76 = 4 S	

and since $\frac{i}{3} = 0.61$, we shall have

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3} = (117.43 + 684.76 + 229.14) \times 0.61 = 629.113,$$

which is the half displacement of the *after* body.

(117.) Hence the whole semi displacement will consist of the

Half displacement of the middle body...	=	50788.19
Half displacement of the fore body	=	941.52
Half displacement of the after body.....	=	629.11
Half displacement of stern port and rudder	=	87.46
Half displacement of head before the rabbit........................	=	14.14
Half displacement of the ship......		52460.42

(118.) Such is the mode of computing the displacement by means of vertical sections. Let us now proceed to estimate the same by means of horizontal sections. To accomplish this, the area of each horizontal section must be found, and we select as an example that of the load water line.

(119.) This load water line* is divided, by means of the assumed points E F, into three portions, denominated the *middle space*, the *fore space*, and the *after space*. The area of each of these must be computed by means of the proper formula. Example of an horizontal section.

MIDDLE SPACE, *comprised between the points* E F.

This portion we shall compute by means of the formula

$$(S + 2\,P + 3\,Q)\,\frac{3\,i}{8}.$$

* We add in a note the absolute areas in feet of the light and

Extreme Ordinates.	Second Class of Ordinates.	Third Class of Ordinates.
1..16.05	4..22.70	2..19.31
28..18.55	7..24.48	3..21.33
34.60 = S	10..24.90	5..23.60
	13..24.90	6..24.13
	16..24.90	8..24.72
	19..24.84	9..24.85
	22..24.70	11..24.90
	25..23.72	12..24.90
	195.14	14..24.90
	2	15..24.90
		17..24.90
	390.28 = 2 P	18..24.85
		20..24.83
		21..24.76
		23..24.53
		24..24.23
		26..22.87
		27..21.18
		429.69
		3
		1289.07 = 3 Q

and since $\frac{3\,i}{8} = 2.25$, we shall have

$$(\mathrm{S} + 2\,\mathrm{P} + 3\,\mathrm{Q})\,\frac{3\,i}{8} = (34.6 + 390.28 + 1289.07)$$
$$\times\, 2.25 = 1713.95 \times 2.25 = 3856.3875,$$

which is half the area of the middle space.

load water lines for the several classes of ships, together with the proportional numbers, assuming the area of the light water line at 100.

Class of Ships.		Area in Feet of the Light Water line.	Area in Feet of the Load Water line.	Proportional Numbers.	
	120	8662	10096	100	117
	80	7409	9065	100	122
	74	6120	7517	100	117
Razée..........	50	6016	7190	100	120
	52	5436	6777	100	125
	46	3920	5143	100	131
Razée corvette ..	26	3753	4734	100	126
	28	2774	3144	100	113
Corvette........	18	2376	2960	100	125
Gun-brig.......	18	1911	2392	100	125
	10	1488	1842	100	124
Schooner..........		1118	1447	100	129
Cutter.............		924	1200	100	130
New Class of Ships.					
London........	92	8484	9866	100	116
Castor.........	36	4840	6036	100	125
Vernon........	50	6198	7782	100	126
Rover.........	18	2187	3034	100	139
Snake.........	16	1760	2401	100	136

Here it may be remarked, that the ratios of the areas of the light and load water lines are precisely the same in the 120 and 74-gun ships, and that the new class of the London approaches extremely near to them. The Razée corvette of 26 and the new class Vernon are likewise identical in this particular. The 52-gun ship, the Castor of 36, the 18-gun corvette, and the 18-gun brig, are also precisely the same. The nearest approach to equality in these areas is in the corvette of 28 guns, and the greatest disparity exists in the new class of the Rover of 18 guns.

Fore Space, *or part before the point* F.

This portion we shall compute by means of the formula $(\Sigma + 4\,\mathrm{S} + 2\,s)\frac{i}{3}$

Extreme Ordinates.	Even Ordinates.	Odd Ordinates.
1..18.55	2..16.40	3..13.30
5..0.80	4..8.72	2
19.35 = Σ	25.12	26.60 = 2 s
	4	
	100.48 = 4 S	

and since $\frac{i}{3} = 1$, we shall have

$$(\Sigma + 4\,\mathrm{S} + 2\,s)\,\frac{i}{3} = (19.35 + 100.48 + 26.60)$$
$$\times\, 1 = 146.43.$$

If to this there be added the area of the section of the stem and knee-head, amounting to 2.63, we shall have for the total semi area of the fore space, the quantity 149.06.

After Space, *or part abaft the point* E.

This portion we shall compute by the same formula.

Extreme Ordinates.	Even Ordinates.	Odd Ordinates.
1...16.05	2...14.69	3..12.87
7...0.80	4...10.60	5...7.51
16.85 = Σ	6...3.80	20.38
	29.09	2
	4	40.76 = 2 s
	116.36 = 4 S	

and since $\frac{i}{3} = 0.61$, we shall have

$$(\Sigma + 4\,\mathrm{S} + 2\,s)\,\frac{i}{3} = (16.85 + 116.36 + 40.76)$$
$$\times\, 0.61 = 106.1217.$$

If to this there be added the area of the section of the post and rudder, amounting to 3.6, we shall have 109.7217 for the total semi area of the fore space.

(120.) Hence the entire semi area of the load water line will consist

The semi area of the middle space. ..	=	3856.3875
semi area of the fore space	=	149.06
semi area of the after space....	=	109.7217
semi area of the load water line.	=	4115.1692

(121.) In the same way may the semi areas of all the other horizontal sections be obtained, the successive results being entered in the last vertical column of the Table.

To apply these areas to the displacement, it is to be remarked, that the body of the vessel is supposed to be divided into two portions, denominated respectively the *upper body* and the *lower body*, each of which we shall proceed to compute.

Upper Body.

Extreme Areas.	Even Areas.	Odd Areas.
1.4115.17	2..3884.75	5..3510.34
5..2450.67	4..3028.73	2
6565.84 = Σ	6913.48	7020.68
	4	
	27653.92 = 4 S	

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and since $\frac{i}{3} = 1$, we shall have

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3} = (6565.84 + 27653.92 + 7020.68) \times 1 = 41240.44$$

for the semi displacement of the upper body.

In like manner we proceed to the computation of the

Lower Body.

Extreme Areas.	Even Areas.	Odd Areas.
1..2450.67	2..2290.92	3..2128.97
2 . 235.65	4..1977.61	5..1783.96
2686.32 = Σ	6..1591.72	7..1356.64
	8..1033.54	9.. 615.79
	10.. 392.99	5885.36
	7286.78	2
	4	11770.72 = 4 s
	29147.12 = 4 S	

and since $\frac{i}{3} = 0.25$, we shall have

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3} = (2686.32 + 29147.12 + 11770.72) \times 0.25 = 10901.04 \text{ cubic feet}$$

for the semi displacement of the lower body.

(122.) Hence the whole semi displacement by horizontal sections will be

Semi displacement of upper body....	=	41240.44
Semi displacement of lower body....	=	10901.04
* Semi displacement of solid below lower body....................	=	107.13
Semi displacement of keel and rudder, &c.	=	217.18
Semi displacement by horizontal sections........................	=	52465.79

A mean of the vertical and horizontal sections should be taken.

(123.) To ensure accuracy, a mean of the displacements calculated by the vertical and horizontal sections should be taken, amounting in the present instance to 52463.1. Hence the whole displacement will be 104926.2; or dividing by 35 the number of cubic feet of sea-water in a ton, the absolute displacement in tons will be 2998.89 tons.

Table to show in what way the displacement is made up.

(124.) To show in what way the displacement is made up by the different weights, constituting the hull and stores, &c. of each vessel, we have drawn from Mr. Edye's *Naval Calculations* the following important particulars.

Weight of the various Articles composed in the Hull of each Ship and Vessel.†

Number of guns	120	80	74	Razée. 50	52	46	Razee Corvette. 26	28	Corvette. 18	Brig. 18	Brig. 10	Schooner.	Cutter.
	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons Cwt.
Weight of timber ..	2197 10	1653 11	1406 2	1255 10	904 0	690 13	615 6	358 14	238 0	175 4	132 18	89 10	68 12
— iron............	136 0	119 10	109 4	96 13	67 0	53 7	39 0	23 5	16 15	15 10	8 0	7 10½	5 1½
— copper bolts	47 14	40 0	37 13	36 13	23 0	15 0	13 10	8 5	5 2	4 17	3 11	2 15	1 17
— copper sheets (1.)	17 19	14 12	12 14	11 18	11 7	9 4	7 14	5 10	5 2	3 19	3 3	2 12	2 1
— mixed metal nails	2 18	2 5	2 2	1 14	1 18	1 12	1 10	0 18	1 1	0 12½	0 10½	0 8¾	0 6¾
— pintles and braces	2 11	2 3	1 15	1 15	1 15	1 9	1 0	0 11	0 11½	0 5½	0 5	0 4¼	0 4¼
— lead of all sorts ..	9 0	8 9	8 0	7 10	7 2	5 4	4 9	4 10	4 7	4 2	3 0	2 3	1 2
— oakum	16 1	13 10	11 10	9 7	6 10	4 18	4 1	4 0	3 12	3 0	2 0	1 12	1 8
— barrels of pitch (2.)	5 7	4 6	4 12	3 18	3 17	2 18	1 17	1 5	1 3	1 4	0 15	0 15	0 11
— barrels of tar (3.)	11 13	11 7	11 5	11 5	7 0	4 13	4 2	2 7	1 18	1 15	0 15	0 11½	0 10½
— whiting and white lead	9 10	6 12	6 8	6 8	4 12	2 12	2 7	2 4	1 12	1 5	0 15	0 13	0 5
— linseed oil (4.) ...	1 5	1 5	1 5	1 5	1 1	0 18	0 16	0 6	0 4½	0 3	0 2	0 1½	0 0¾
— three coats of paint	9 10	4 16	4 5	4 2	3 10	2 15	2 8	2 2	1 15	1 13	0 13½	0 9¼	0 7½
Ship's weight when launched.....	2466 18	1882 6	1616 15	1447 18	1042 12	795 3	698 0	413 17	281 3	213 10	156 8	109 6	82 7

* It is but rarely that the load water line is parallel to the keel, and the same may be said of the light water line. In the different classes of ships which follow, the excess of the after load draught above the forward load draught is given in the second column, and similar differences of the light water draught are recorded in the last.

Class of Ships.	Excess of after load draught above forward load draught. Ft.	In.	Excess of after load draught above forward light draught. Ft.	In.
120	1	5	2	4
80	3	3	4	7
74	2	10	4	1
52	1	0	2	10
46	1	8	4	9
28	0	5	2	2
Corvette..18	0	7	1	10
Brig 18	3	3	4	10
Brig 10	1	1	2	5
Schooner..10	2	6	2	11
Cutter	6	10	6	6

In every instance, excepting the cutter, the difference of the after and forward light water draughts exceeds the difference of the corresponding load water draughts. In calculating the load or light displacements, it is manifest in carrying down the successive horizontal planes, that a portion of the vessel must remain, requiring a separate computation, in all cases where the two draughts of water are not precisely the same.

Actual weights of certain important elements.

† We throw into a note some numerical results connected with the weight of weights contained in the preceding Table, on account of their great importance to the ship-builder. Such results illustrate in a high degree the statistics of ship-building, and are also of great value in

Weight of the Masts and Yards, and of the Spare Gear, Rigging, and Blocks, of the Sails, Cables, and Anchors, Water, Provisions, and Men; of the Powder; Gunner's, Boatswain's, and Carpenter's Stores; of the Guns and Shot, and weight of the Boats when fitted for Foreign Service.

Number of guns	120	80	74	Razée. 50	52	46	Razée Corvette. 26	28	Corvette. 18	Brig. 18	Brig. 10	Schooner.	Cutter.
	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.	Tns.Ct.Qr.
Lower masts and bowsprit	52 12 1	51 18 2	36 14 0	38 14 0	34 2 0	21 12 3	21 5 1	9 2 0	9 2 0	7 9 2	4 5 2	6 8 0	5 9 2
Topmasts and yards aloft	37 1 3	37 1 3	27 11 0	27 11 0	27 11 0	18 12 3	18 12 3	8 15 2	8 15 2	7 3 1	5 15 1	1 18 2	2 12 0
Spare gear and booms	16 11 3	16 11 3	12 12 0	12 12 0	12 12 0	7 10 2	7 10 0	4 2 0	4 2 0	3 0 2	2 4 3	1 3 0	....
The rigging. Standing (5.) ..	29 6 0	28 6 0	26 19 0	28 10 0	25 4 0	14 13 0	14 13 0	12 10 0	12 18 0	5 0 0	3 5 0	2 2 0	3 13 0
Running	18 2 0	17 4 0	16 18 0	17 15 0	16 5 0	11 7 0	11 7 0	6 10 0	6 16 0	4 10 0	2 16 0	1 • 8 2	
Blocks	12 3 0	11 2 0	10 12 0	10 12 0	10 0 0	5 8 0	5 8 0	4 4 0	4 4 0	2 0 0	1 0 0	0 6 3	
Ship's sails (6.).....	6 19 3	7 5 2	6 0 2	6 14 0	6 1 0	3 15 2	3 17 0	2 2 3	2 5 1	1 11 3	1 4 2	1 5 0	1 17 0
Spare sails (7.)	4 4 0	4 7 0	3 14 1	4 5 0	3 14 0	2 5 2	2 6 0	1 9 3	1 13 1	1 5 2	0 17 1	0 16 0	0 5 1
Hempen cables (8.) .	32 10 0	29 15 0	25 4 0	25 4 0	25 4 0	13 1 0	9 13 0	6 19 0	6 19 0	4 1 0	1 16 0	0 8 1	....
Iron cables (9.)	37 3 0	36 11 0	30 17 0	30 17 0	30 17 0	26 2 0	26 2 0	15 18 0	15 18 0	10 8 0	7 1 0	6 6 3	3 90
Anchors	20 16 2	17 8 0	15 5 0	15 5 0	12 10 2	10 1 0	8 11 0	4 5 2	4 5 2	3 10 2	2 14 0	2 2 3	1 72
	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt.	Tons. Cwt	Tons. Cwt.	Tons. Cwt.	Tons. Cwt	Tons Cwt
Iron ballast and tanks	373 0	247 0	196 0	100 0	187 0	107 10	84 0	81 to 55	77 0	47 0	25 0	30 0	32 0
Water	410 15	385 0	260 9	175 0	220 0	110 0	106 0	55 5	50 0	32 0	19 0	11 0	4 5
Coals and wood	100 0	78 0	52 0	45 0	38 0	32 0	21 0	15 0	10 0	8 10	6 0	4 0	2 0
Provisions, spirits, and slops.......	296 4	241 15	211 18	134 3	113 0	69 4	59 0	31 15	28 10	23 14	6 10	6 8	3 2
Men, chests, &c. ...	102 6	78 0	65 0	48 0	45 0	27 3	20 0	18 2	14 7	14 7	8 14	4 12	2 15
Gunner's stores	39 12½	27 2	22 2	18 0	16 0	12 11	11 10	7 10	6 5	5 17	2 2	1 8	0 18
Boatswain's and carpenter's stores ..	54 0	51 15	48 0	46 0	39 0	31 0	31 0	16 0	14 10	12 5	8 7	4 2¼	4 12
Guns, &c.	329 18	224 5	178 7	150 18	125 4	80 7	68 8	31 3	21 17	21 17	8 2¼	4 7½	3 8
Powder, &c.	33 5	25 0	20 16½	18 12	13 18	11 18¾	9 5	4 18¾	2 15	2 15	1 10	0 11½	0 11
Shot and cases	125 14	98 12	79 17	80 12	58 2	45 10	38 15	30 3	22 2	22 2	6 0	2 5½	2 10
Launch	5 8	5 2	5 2	5 2	4 3½	4 3½	....	....	....	....	....	....	....
Cutter	2 No. 1 3	2 No. 1 3	2 No. 1 3	2 No. 1 2	2 No. 1 3	2 No. 1 3	2 No. 1 3	0 14¾	0 10¾	0 10¾	Yawl 1 3	0 16	0 16
Barge	1 10	1 10	1 10	1 10	1 10	Commodore. 1 10	Cutter. 0 14½	2 Cutter gigs. 1 6	0 8	0 8	....	....	....
Pinnace	1 10	1 10	1 10	1 10	1 5¼	1 10	1 10	1 5¼	1 5¼	1 5¼	....	....	....
Gig	....	....	....	0 10¾	....	....	0 9½	....	....	....	0 9	0 13	0 13¼
Jolly-boat	0 9¼	0 9¾	0 9¾	0 9½	0 9¾	0 9¾	....	0 9¾	0 7¼	0 7¾	0 9¾	0 7¾	0 4½

(125.) As the various particulars contained in the preceding Table are necessarily separated into two great divisions, one of which comprises the weight of the hull when launched, and the other the different weights received on board, we throw their aggregates into the succeeding Table.

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assisting the computer in estimating the amount of actual expenditure, a matter of the greatest moment to a Naval Country, and particularly so at a time when such gigantic vessels are constructing.

Number of guns	120	80	74	Razée. 50	52	46	Razée Corvette. 26	28	Corvette. 18	Brig. 18	Brig. 10	Schooner.	Cutter.
(1.) Number of sheets of copper sheathing ..... 28 oz.	1166	1800	1472	1329	1350	1000	850	790	850	797	580	652	550
32 oz.	3572	2050	1734	1706	1650	1170	1130	600	613	301	200	80	..
Number of treenails	64,458	35,103	27,019	25,380	23,500	20,826	17,300	14,540	13,050	11,193	8,316	7,100	3,250
(2.) Number of barrels of pitch .	50	45	43	37	36	25	18	12	11	11	7	7	5
(3.) Number of barrels of tar ...	109	106	105	105	66	44	39	22	18	16	7	5¾	5
(4.) Number of gallons of linseed oil	400	400	400	400	320	282	256	96	60	48	32	23	11
(5.) Number of fathoms of rope from ¾ to 18 inches in circumference	30,250	32,400	27,152	29,200	28,700	20,728	21,370	19,031	19,350	10,709	7,335	....	..
Number of blocks.............	940	940	934	934	934	893	893	848	848	576	399	....	..
(6.) Number of yards of canvass in ship's sails	12,517	12,947	10,784	11,130	10,824	7307	7381	4796	5096	3547	2740	2790	4140
(7.) Number of yards of canvass in spare sails	7584	7844	6650	6876	6690	5066	5140	3322	3720	2847	1916	1750	589
	Brs Stm.	Brs Stm.	Brs Stm.	Brs Stm.	Brs Stm.	Brs Stm.	Brs. Stm.	Brs Stm.	Brs. Stm.	Brs Stm.	Brs Stm.	Brs. Stm.	Brs Stm.
(8.) Number of hempen cables..	5 1	5 1	5 1	5 1	5 1	4 1	3 1	3 1	3 1	2 1	1 1	0 1	..
(9.) Number of iron cables	3 1	3 1	3 1	3 1	3 1	3 1	3 1	3 1	3 1	3 1	2 1	3 0	3 1

Number of Guns....	120		80		74		Razée. 50		52		46		Razée Corvette. 26		48		Corvette. 18		Brig. 18		Brig. 10		Schooner.		Cutter	
	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.	Tons.	Cwt.
Weight of the hull when launched..	2466	18	1882	6	1616	15	1447	18	1042	12	795	3	698	0	413	17	281	3	213	10	156	8	109	6	82	7
Weight received on board	2142	5	1723	14	1359	11	1044	8	1067	16	670	9	582	0	370	11	326	16	242	18	126	6	94	17	76	8
Total weight when complete	4609	3	3606	0	2976	6	2492	6	2110	8	1465	12	1280	0	784	8	607	19	456	8	282	14	204	3	158	15

Weight of a cubic foot of timber green and seasoned.

(126.) In the following Table will be found the weight of a cubic foot of timber in a green and seasoned state, at present used in ships and vessels of war, derived also from Mr. Edye's *Naval Calculations.* This Table will assist the ship-builder in determining the weight of the timber materials necessary in computing a ship's displacement.

Names of Timber.		Green. lbs.	oz.	Seasoned. lbs.	oz.
English oak		71	10	43	8
Dantzic oak		49	14	36	0
African teak		63	12	60	10
Indian teak, green or seasoned, about the same	Malabar	...		52	15
	Rangoon	...		26	4
Indian mast peon		48	3	36	0
Cedar		32	0	28	4
Larch		45	0	34	4
Riga fir		48	12	35	8
New England fir		44	12	30	11
Elm		66	8	37	5
Beech		60	0	53	6
Ash		58	3	50	0

The Malabar teak is the heaviest, and the Rangoon the lightest of all Indian teaks used in ship-building.

The average weight of the timber materials in a ship or vessel of war is about 50 pounds to the cubic foot; and for the masts and yards about forty pounds.

Displacement of an inch at light and load water lines.

(127.) It is often necessary to know the amount of the displacement for a single inch in depth, both at the light and load water lines. In like manner, it is useful to know the displacement of one foot of the midship section at the same lines. The results for the different classes of ships in tons are inserted in the next Table, from Mr. Edye's *Naval Calculations.*

Class of Ship.	Guns.	Displacement of one inch at the light line. Tons	Cwt.	Displacement of one inch at the load line. Tons	Cwt.	Displacement of one foot of the midship section at the light line. Tons	Cwt.	Displacement of one foot of the midship section at the load line. Tons	Cwt.
	120	20	12	24	0	16	10	29	17
	80	17	12	21	11	15	18	26	13
	74	15	5	17	17	12	7	21	3
Razée	50	14	6	17	2	11	14	18	4
	52	12	18	16	2	8	9	17	6
	46	9	6	12	5	8	4	14	4
Razée corvette	26	8	18	11	10	6	10	12	15
	28	6	12	7	9	5	1	9	7
Corvette	18	5	13	7	0¾	3	10	7	5
Gun-brig	18	4	10	5	13	3	11	6	10
	10	3	10	4	7	2	10	4	8
Schooner		2	13	3	10	1	13	3	6
Cutter		2	4	2	17	2	4	3	15
New Class of Ships.									
London	92	20	4	23	9¾	16	0	27	2
Castor	36	11	12	14	7½	9	14¾	12	12
Vernon	50	14	15	18	10½	10	14¾	19	12
Rover	18	5	4	7	5	4	2	7	2
Snake	16	4	8	5	14½	4	0	6	12¼

Displacement augmented by motion of the ship and tide.

(128.) It may also be useful to advert to one or two circumstances more which influence the amount of displacement. In what we have before said, the consideration has been limited to the conditions of a ship at rest in still water; but it has been observed, that when the ship and the water are relatively in motion, either by the ship being at rest, and the water in motion, or by the ships moving and the waters being at rest; or again by the ship and water moving with unequal velocities or in different directions, the depth to which the ship sinks must be determined in connection with other considerations. When a vessel is at anchor also in a strong tideway, or at sea under a press of sail, she must sink several inches deeper than when at anchor in still water. Romme observed a frigate which was lashed to a sheer hulk in the river Charente sink two inches deeper when the velocity of the stream was great, than when its motion was only just sensible.

How accounted for.

(129.) This may be accounted for on the principle, that when a particle of water is impressed with motion, and passes along the surface of a body, it no longer exerts a pressure equally in all directions, as in the case of water in a state of rest, but has a greater tendency to escape in the direction of its motion than any other, and hence causes a less vertical pressure on the surface of the body than when at rest. The total pressure of the particles of water in contact with the body being less than before, and having been, when at rest, exactly equivalent to sustain the body, that body must of necessity sink deeper, until a balance is obtained between the vertical pressure and the weight. The pressure of a particle of water in motion is proportional to its depth below the surface of the water, minus the depth due to the velocity estimated in the direction of its motion. Bernoulli, the Abbé Bossut, and Romme proved these principles by experiment.*

* The following simple and decisive experiment was made by Romme. He had two tubes, one of them straight, as *a b*, and the other curved, as *c d e*, fig. 4, but both having open ends, and capable of receiving a float, *g f*, the lower part of which was cork, and the upper a graduated rod. These tubes with their floats were first plunged into still water, and the divisions corresponding with the upper orifices of the tubes observed. The tubes were then placed in running water, the current being in the direction *h i*, and the bent tube *c d e*, with its lower end turned in the same direction. The floats in both tubes were then observed to have sunk an inch below their position in still water. The bent tube was in the next place turned so as to present its orifice to the current, when the float rose an inch above the position it had in still water. The same tube was then placed with the lower end perpendicularly to the direction of the current, when the float sunk an inch below its position in still water. Romme measured the velocity of the current, and found the water ran 70 feet in 30″, or that its velocity was that due to an inch and a line nearly, corresponding with the distance the floats in the tubes were elevated or depressed in the experiments. Other experiments in currents of different velocities produced similar results. In some instances the depression and elevation of the floats were as much as five or six inches, being always the height due to the velocity of the current. He ascertained also that the results were the same, to whatever depth the tubes were plunged into the water.

Difference of immersion of ships in fresh and salt water.

(130.) It is but seldom a ship of war floats in fresh water, though a merchantman may often do so. We, however, insert in the next Table the difference in the immersions of several ships in fresh and sea water, and from which it appears, that a ship of 120 guns sinks nearly six inches deeper in the former than in the latter. The difference also produced in the two load lines from the two specific gravities is worthy of attention. In the ship just adverted to, it amounts to 143 tons 8 cwt. In the last column we have given the quantity necessary to raise or immerse the ship an inch at the load or sea line. This useful Table is due also to Mr. Edye.

Rate of Ship, or her Number of Guns.	The Ship deeper in River Water than in Sea Water.	Difference in the two Load Lines from the Specific Gravity of Fresh and Salt Water.		Quantity to raise or immerse the Ship an Inch at the Load or Sea Line.	
No.	Inches.	Tons.	Cwt.	Tons.	Cwt.
120	$5\frac{7}{8}$	Equal to 143	8	24	0
74	$5\frac{1}{4}$	93	14	17	17
46	$3\frac{5}{8}$	45	6	12	5
28	$3\frac{1}{4}$	24	6	7	9
18	$2\frac{1}{2}$	14	6	5	13
10	$2\frac{1}{8}$	9	6	4	7
Cutter.	$1\frac{3}{4}$	5	2	2	17

Displacement deduced from different specific gravities of water.

(131.) The displacement may be deduced from the different specific gravities of the water in which a vessel floats. For suppose s and s' to be the specific gravities of fresh and salt water, and D and D′ the corresponding displacements; then by a well-known principle in Hydrostatics

$$D\,s = D'\,s',$$

and $$s : s' :: D' : D.$$

Hence $$s' - s : s' :: D - D' : D.$$

Now, since it requires the application of a given weight to change the displacement D′ into D, it is manifest the actual displacement may be found by knowing this weight, and the values of s and s'. Thus suppose it required an additional weight of 25 tons to bring a vessel down, when floating in salt water, to the load line she possessed when swimming in fresh water, a cubic foot of the former weighing 1026 ounces, and of the latter 1000, we shall have

$$\overset{\text{oz.}}{26} : \overset{\text{oz.}}{1000} :: \overset{\text{tons.}}{25} : \overset{\text{tons.}}{961.54}$$

for the actual amount of the displacement sought.

On the Centre of Gravity of the Displacement.

(132.) In attempting to find the centre of gravity of the displacement, a point involving so many important considerations with regard to the stability, it is manifest when the vessel is floating in equilibrium, that it must be somewhere found in the vertical longitudinal section which passes through the middle of the sternpost and stem; and that the question becomes therefore reduced to the finding its position with regard to two coordinate planes, one of which has reference to the position of the point with regard to the length of the vessel, and denoted by E e in the figure, and the other with regard to its depth below the other coordinate plane W w.

How it may be found.

(133.) We have already explained in our Treatise on Mechanics, a mode by which this may be accomplished with respect to both of the planes just mentioned, by what is termed the theory of moments; and it is obvious that with regard to the position of the centre of gravity of the displacement longitudinally, we shall have three separate computations to make, two relating to the middle and fore bodies of the vessel, and to be esteemed *positive*, and a third as respects the after body, to be regarded as *negative*. The general Table of ordinates will furnish us with the necessary elements for this purpose.

(134.) To estimate the moment of the middle body, we must, in the first place, obtain the resulting products recorded in the last column of the next Table.

Number of the Transverse Vertical Sections.	Half Areas of the Vertical Sections comprised between the Sections 1 and 28.	Distances of the Vertical Sections from the Primitive Section E e.	Resulting Products.
1	101.72	0	0.0
2	145.51	6	873.06
3	186.03	12	2232.36
4	224.11	18	4033.98
5	258.25	24	6198.00
6	288.09	30	8642.70
7	312.49	36	11249.64
8	332.15	42	13950.30
9	347.48	48	16679.04
10	359.87	54	19132.98
11	368.57	60	22114.20
12	375.77	66	24800.82
13	380.89	72	27424.08
14	383.83	78	29938.74
15	385.49	84	32381.16
16	385.93	90	34733.70
17	384.01	96	36867.84
18	380.18	102	38778.36
19	375.69	108	40574.52
20	368.18	114	41972.52
21	358.42	120	43010.40
22	346.07	126	43604.82
23	330.17	132	43582.44
24	309.67	138	42734.46
25	284.25	144	40932.00
26	251.31	150	37696.50
27	207.11	156	32309.16
28	151.52	162	24546.24

And to apply these resulting products to the formula

$$(S + 2P + 3Q)\frac{3i}{8},$$

we shall further obtain

Extreme Products.	Second Class of Products.	Third Class of Products.
1... 0.0	4... 4033.98	2... 873.06
28...24546.24	7...11249.64	3... 2232.36
	10...19132.98	5... 6198.00
24546.24 = S	13...27424.08	6... 8642.70
	16...34733.70	8...13950.30
	19...40574.52	9...16679.04
	22...43604.82	11...22114.20
	25...40932.00	12...24800.82
		14...29938.74
	221985.72	15...32381.16
	2	17...36867.84
		18...38778.36
	443971.44 = 2P	20...41972.52
		21...43010.40
		23...43582.44
		24...42734.46
		26...37696.50
		27...32309.16
		474762.06
		3
		1424286.18 = 3Q

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and since $\frac{3i}{8} = 2.25$, we shall have

$$(S + 2P + 3Q)\frac{3i}{8} = (24546.24 + 443971.44 + 1424286.18) \times 2.25 = 4258808.685$$

for the moment of the half middle body.

(135.) To compute, in the next place, the moment of the fore body, it is to be observed that the distances of the successive vertical sections in it must still be estimated from the primitive plane E *e*, and therefore gives for the interval between the section passing through the point 2 in the fore body, and that plane, 165 feet. Hence we shall obtain the following resulting products.

Number of the Transverse Vertical Sections.	Half Areas of the Vertical Sections comprised between the Sections F *f* and 5.	Distances of the Vertical Sections from the Primitive Section E *e*.	Resulting Products.
28.1	151.52	162	24546.24
2	118.41	165	19537.65
3	79.76	168	13399.68
4	37.97	171	6492.87
5	4.96	174	863.04

To apply these resulting products to the formula

$$(\Sigma + 4S + 2s)\frac{i}{3},$$

we shall have

Extreme Products.	Even Products.	Odd Products.
1..24546.24	2..19537.65	3..13399.68
5.. 863.04	4.. 6492.87	2
25409.28 = Σ	26030.52	26799.36 = 2*s*
	4	
	104122.08 = 4S	

and since $\frac{i}{3} = 1$, we shall have

$$(\Sigma + 4S + 2s)\frac{i}{3} = (25409.28 + 104122.08 + 26799.36) \times 1 = 156330.72$$

for the moment of the half fore body, exclusive of the knee of the head amounting to 2474.64. Hence the entire moment of the half fore body will amount to 158805.36.

(136.) To estimate the moment of the after body, the distances of the vertical sections in it must in like manner be estimated from the same primitive vertical section E *e*. This will give the resulting products in the last column of the next Table.

Number of Transverse Vertical Sections.	Half Areas of the Vertical Sections comprised between E *e* and 7.	Distances of the Vertical Sections from the Primitive Section E *e*.	Resulting Products.
1	101.72	0.0	0.0
2	87.81	1.83	160.69
3	72.63	3.66	265.83
4	57.88	5.49	317.76
5	41.94	7.32	307.00
6	15.66	9.15	143.29
7	15.71	10.98	172.50

To apply these resulting products to the formula

$$(\Sigma + 4S + 2s)\frac{i}{3},$$

we shall have

Extreme Products.	Even Products.	Odd Products.
1... 0.0	2...160.69	3...265.83
7...172.5	4...317.76	5...307.00
172.5 = Σ	6...143.29	572.83
	621.74	2
	4	1145.66 = 2*s*
	2486.96 = 4S	

and since $\frac{i}{3} = 0.61$, we shall have

$$(\Sigma + 4S + 2s)\frac{i}{3} = (172.5 + 2486.96 + 1145.66) \times 0.61 = 2321.1232,$$

which is the moment of half the after body exclusive of the post and rudder. And since the moment of the post and rudder amounts to 1141.35, we shall have for the entire moment of the semi after body, the quantity 3462.4732.

(137.) Now since by the conditions of the primitive plane E *e*, the moments of the middle and fore body are regarded as positive, and that of the after body is negative, we shall have for the absolute amount of the moments,

Moment of the half middle body. .	=	+ 4258808.685
Moment of the half fore body. . . .	=	+ 158805.36
		+ 4417614.045
Moment of the semi after body . .	=	− 3462.4732
Absolute amount of the moments .	=	+ 4414151.5718

(138.) And since by well-known considerations, the position of the centre of gravity with regard to the primitive vertical plane may be found by the formula $\frac{M}{D}$, where M represents the sum of the moments, and D denotes the corresponding displacement, and that we have already found D = 52460.42, we shall hence have

$$\frac{M}{D} = \frac{4414151.5718}{52460.42} = 84.14,$$

which is the distance of the centre of gravity of the displacement before the primitive section E *e*. And since the distance from this same section to the middle point of the load water section is 81.50 feet, it is manifest that the centre of gravity of the displacement is before the middle of the length of the load water section, when measured from the after part of the rabbet of the sternpost to the fore part of the rabbet of the stem, 2.64 feet.

Position of the centre of gravity of displacement with regard to the length,

(139.) To proceed in the next place to the computation of the depth of the centre of gravity of the displacement below the plane of the load water section, we must compute separately the moments of the upper and lower bodies. The preparatory products for the former of these are given in the next Table.

and with regard to the depth.

Number of the Water Sections.	Half Areas of the Water Sections.	Distances of the Water Sections from the Load Water Section.	Resulting Products.
1	4115.17	0	0.0
2	3884.75	3	11654.25
3	3510.34	6	21062.04
4	3028.73	9	27258.57
5	2450.67	12	29408.04

And to apply these resulting products to the formula

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3},$$

we shall have

Extreme Products.	Even Products.	Odd Products.
1.. 0.0	2.. 11654.25	3.. 21062.04
5.. 29408.04	4.. 27258.57	2
29408.04 = Σ	38912.82	42124.08 = 2*s*
	4	
	155651.28 = 4S	

and since $\frac{i}{3} = 1$, we shall have

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3} = (29408.04 + 155651.28 + 42124.08) \times 1 = 227183.4$$

for the moment of the half upper body.

(140.) Pursuing the same course for the half lower body, we shall in the first place obtain the results of the next Table.

Number of the Water Sections.	Half Areas of the Water Sections.	Distances of the Water Sections from the Load Water Section.	Resulting Products.
1	2450.67	12.00	29408.04
2	2290.92	12.75	29209.23
3	2128.97	13.50	28741.10
4	1977.61	14.25	28180.94
5	1783.96	15.00	26759.40
6	1591.72	15.75	25069.59
7	1356.64	16.50	22384.56
8	1033.54	17.25	17828.56
9	615.79	18.00	11084.22
10	392.99	18.75	7368.56
11	235.65	19.50	4595.17

To apply these successive products to the formula

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3},$$

we shall have

Extreme Products.	Even Products.	Odd Products.
1...29408.04	2...29209.23	3...28741.09
11... 4595.17	4...28180.94	5...26759.40
	6...25069.59	7...22384.56
34003.21 = z	8...17828.56	9...11084.22
	10... 7368.56	
	107656.88	88969.27
	4	2
	430627.52 = 4 S	177938.54 = 2*s*

and since $\frac{i}{3} = 0.25$, we shall have

$$(\Sigma + 4\,S + 2\,s)\,\frac{i}{3} = (34003.21 + 430627.52 + 177938.54) \times 0.25 = 160642.3175,$$

which is the moment of half the lower body,

(141.) Hence the sum of all the moments of the immersed body will be:

Moment of half the upper body...	= + 227183.40
Moment of half the lower body...	= + 160642.3175
Moment of half the solid below the lower body............	= + 2121.17
Moment of half keel, rudder, &c...	= + 6767.90
Total sum of all the moments..	= + 396714.7875

And since as before the function $\frac{M}{D}$ represents the distance of the centre of gravity of the displacement below the assumed plane of the water section, we shall have

Its position.

$$\frac{M}{D} = \frac{396714.7875}{52460.42} = 7.56 \text{ feet}$$

for that distance.

(142.) It forms a useful subject for investigation in many important points connected with ship-building, to be enabled to compare the centre of gravity of the load water section so often referred to, with the centre of gravity of the displacement, reckoned in the same horizontal direction; and also the centre of gravity of the midship section, with the corresponding position of the same point of the immersed volume. The same process must be employed for obtaining the centre of gravity of the surface as for the solid; and in the same manner as for the solid, the moments of the load water line must be separated into the middle space, the fore space, and the after space, and each have its proper sign of *plus* or *minus* prefixed to it, according as it is situated with regard to the primitive section passing through the point E.

Useful to compare centre of gravity of load water section with centre of gravity of displacement.

Number of the Ordinates.	Ordinates of the Load Water Section in the Middle Space.	Distances of the Ordinates from the Primitive Ordinate E.	Resulting Products.
1	16.05	0	0.0
2	19.31	6	115.86
3	21.33	12	255.96
4	22.70	18	408.60
5	23.60	24	566.40
6	24.13	30	723.90
7	24.48	36	881.28
8	24.72	42	1038.24
9	24.85	48	1192.80
10	24.90	54	1344.60
11	24.90	60	1494.00
12	24.90	66	1643.40
13	24.90	72	1792.80
14	24.90	78	1942.20
15	24.90	84	2091.60
16	24.90	90	2241.00
17	24.90	96	2390.40
18	24.85	102	2534.70
19	24.84	108	2682.72
20	24.83	114	2830.62
21	24.76	120	2971.20
22	24.70	126	3112.20
23	24.53	132	3237.96
24	24.23	138	3343.74
25	23.72	144	3415.68
26	22.87	150	3430.50
27	21.18	156	3304.08
28	18.55	162	3005.10

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To adapt these resulting products to the formula

$$(S + 2P + 3Q)\,\frac{3i}{8},$$

we shall have

Extreme Products.	Second Class of Products.	Third Class of Products.
1.. 0.0	4.. 408.60	2.. 115.86
28..3005.1	7.. 881.28	3.. 255.96
3005.1=S	10..1344.60	5.. 566.40
	13..1792.80	6.. 723.90
	16 .2241.00	8 .1038.24
	19..2682.72	9..1192.80
	22..3112.20	11..1494.00
	25..3415.68	12..1643.40
	15878.88	14..1942.20
	2	15..2091.60
		17..2390.40
	31757.76=2P	18..2534.70
		20..2830.62
		21..2971.20
		23..3237.96
		24..3313.74
		26..3430.50
		27..3304.08
		35107.56
		3
		105322.68=3Q

and since $\frac{3i}{8} = 2.25$, we shall have

$$(S + 2P + 3Q)\,\frac{3i}{8} = (3005.1 + 31757.76 + 105322.68) \times 2.25 = 315192.465,$$

which is the moment of the middle space.

(143.) In a similar manner we must proceed to the computation of the moments of the fore space.

Number of the Ordinates.	Ordinates of the Load Water Section in the Fore Space.	Distances of the Ordinates from the Primitive Ordinate E	Resulting Products.
28..1	18.55	162	3005.10
2	16.40	165	2706.00
3	13.30	168	2234.40
4	8.72	171	1491.12
5	0.80	174	139.20

Applying these resulting products to the formula

$(\Sigma + 4S + 2s)\frac{i}{3}$, we shall have

Extreme Products.	Even Products.	Odd Products.
1..3005.10	2..2706.00	3..2234.10
5.. 139.20	4..1491.12	2
3144.30 = Σ	4197.12	4468.20 = 2s
	4	
	16788.48 = 4S	

and since $\frac{i}{3} = 1$, we shall obtain

$$(\Sigma + 4S + 2s)\,\frac{i}{3} = (3144.30 + 16788.48 + 4468.20) \times 1 = 24400.98$$

for the moment of the fore space. Adding to this the moment of the stem section amounting to 462.93, we shall have for the whole moment of the fore space the quantity 24863.91.

(144.) In the same way we must proceed for the moments of the after space.

Number of the Ordinates.	Ordinates of the Load Water Section in the after Space.	Distances of the Ordinates from the Primitive Ordinate E	Resulting Products.
1	16.05	0.0	0.0
2	14.69	1.83	26.88
3	12.87	3.66	47.10
4	10.60	5.49	58.19
5	7.51	7.32	54.97
6	3.80	9.15	34.77
7	0.80	10.98	8.78

Applying these resulting products to the formula

$$(\Sigma + 4S + 2s)\,\frac{i}{3},$$

we shall have

Extreme Products.	Even Products.	Odd Products.
1....0.00	2....26.88	3....47.10
7....8.78	4....58.19	5....54.97
8.78=Σ	6....34.77	102.07
	119.84	2
	4	204.14 = 2s
	479.36 = 4S	

and since $\frac{i}{3} = 0.61$, we shall obtain

$$(\Sigma + 4S + 2s)\,\frac{i}{3} = 422.29$$

for the moment of the after space, exclusive of the post and rudder, amounting to 47.70. Hence the entire moment of the after body will be 469.99.

(145.) The moments of the middle and fore space being regarded as *positive*, that of the after space must be esteemed *negative*. Hence we shall have

Moment of middle space..........	=	+ 315192.465
Moment of fore space............	=	+ 24863.910
		+ 340056.375
Moment of after space	=	− 469.990
Absolute amount of the moments of the water section.............		+ 339586.385

(146.) Now, by the last column of the general Table of ordinates it appears, that the semi horizontal area of the water section amounts to 4115.17; and hence the function

$$\frac{M}{D} = \frac{339586.385}{4115.17} = 82.52 \text{ feet.}$$

Position of centre of gravity of load water section.

(147.) The centre of gravity of the load water section is thus found to be 82.52 feet from the ordinate 1; and since the distance of the middle point from the same ordinate is 81.50, the distance of the centre of gravity of the load water line before the middle is 1.02 feet.

(148.) Thus it appears, that the centre of gravity of the load water section is not so far before the middle as

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the centre of gravity of the displacement itself, which is a principle to be observed in the construction of ships.

Positions of centre of gravity of displacement in several classes of ships.

(149.) We throw into the next Table the positions of the centre of gravity of displacement in the several classes of ships: first, with regard to the centre of the plane of flotation; secondly, as to its position *above* the lower side of the keel; and thirdly, as regards its depth *below* the load water line. These important elements have been drawn from Mr. Edye's admirable Tables.

Class of Ship.		Distance of the Centre of Gravity of Displacement before the Centre of Flotation.		Distance of the Centre of Gravity of Displacement above the lower side of the Keel.		Distance of the Centre of Gravity of Displacement below the Load Water Line.	
	Guns.	Ft.	In.	Ft.	In.	Ft.	In.
	120	2	$7\frac{3}{4}$	16	$8\frac{1}{2}$	8	7
	80	1	$9\frac{1}{8}$	14	$11\frac{3}{8}$	8	$4\frac{1}{8}$
	74	1	$10\frac{7}{8}$	14	$3\frac{1}{2}$	8	$0\frac{1}{2}$
Razée	50	1	$9\frac{3}{4}$	13	$8\frac{1}{4}$	7	$2\frac{1}{4}$
	52	2	$8\frac{1}{4}$	13	$3\frac{3}{8}$	6	$7\frac{5}{8}$
	46	3	$9\frac{3}{4}$	12	$6\frac{1}{4}$	5	$9\frac{3}{4}$
Razée corvette...	26	2	3	11	$8\frac{1}{2}$	6	$0\frac{1}{4}$
	28	1	10	10	$5\frac{5}{8}$	4	$10\frac{7}{8}$
Corvette........	18	2	$3\frac{1}{2}$	10	$9\frac{3}{8}$	4	$2\frac{1}{8}$
Gun-brig	18	1	$7\frac{1}{2}$	8	$11\frac{1}{2}$	4	$0\frac{1}{2}$
	10	1	$3\frac{1}{8}$	8	$2\frac{1}{8}$	3	$9\frac{3}{8}$
Schooner		3	$1\frac{1}{4}$	7	$3\frac{1}{8}$	3	$1\frac{7}{8}$
Cutter.		1	$1\frac{1}{8}$	8	$0\frac{1}{8}$	3	$0\frac{7}{8}$
NEW CLASS OF SHIPS.							
London	92	3	5	15	$5\frac{3}{8}$	8	$3\frac{5}{8}$
Castor	56	3	$7\frac{7}{8}$	13	$5\frac{1}{8}$	6	$1\frac{5}{8}$
Vernon.........	50	3	$9\frac{3}{4}$	14	$3\frac{1}{8}$	6	$11\frac{7}{8}$
Rover..........	18	3	$3\frac{1}{2}$	10	2	4	4
Snake	16	3	$1\frac{3}{4}$	9	$10\frac{3}{4}$	4	$2\frac{3}{4}$

The nearest approach of the centre of gravity of displacement to the centre of flotation is in the cutter, and the next to it is the 18-gun-brig. The two points are at the greatest distance in the Vernon.

On the Centres of Gravity of the Solids of Immersion and Emersion.

Centres of gravity of solids of immersion and emersion.

(150.) It is not only of importance that the true amount of the solids of immersion and emersion should be calculated, but the positions of their centres of gravity also, in order to discover if they are found in the same transverse section, or at the same common distance before the aftermost section. Supposing the result of the computation should prove this not to be the case, such alterations must be made in the body as the results seem to require.

(151.) To determine in the first place the distance forward of the IMMERSIONS CENTRE OF GRAVITY, we must remember there are three systems of moments to compute; *viz.* those in the MIDDLE BODY, the FORE BODY, and the AFTER BODY.

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MOMENTS IN THE MIDDLE BODY.

Extreme Products.	Second Class of Products.	Third Class of Products.
1. . 0000.00	4. . 841.50	2. . 199.38
28. . 5052.78	7. . 1683.54	3. . 461.52
5052.78 = S	10. . 2678.94	5 . 1065.'0
	13. . 3622.32	6. . 1373.70
	16. . 4527.90	8 . 2010.54
	19. . 5385.42	9. . 2369.76
	22. . 6258.42	11. . 3003.60
	25. . 6720.48	12. . 3320.46
	31718.52	14. . 3924.18
	2	15. . 4226.04
	63437.04 = 2P	17. . 4817.28
		18. . 5093.88
		20. . 5671.50
		21. . 5966.40
		23. . 6515.52
		24. . 6701.28
		26. . 6543.00
		27. . 6102.72
		69366.36
		3
		208099.08 = 3Q

and since $\frac{3\,i}{8} = 2.25$, we shall have

$$(\text{S} + 2\,\text{P} + 3\,\text{Q})\,\frac{3\,i}{8} = (5052.78 + 63437.04 + 208099.08) \times 2\ 25 = 622325.025,$$

which is the moment of the middle body.

MOMENTS IN THE FORE BODY.

Extreme Products.	Even Products.	Odd Products.
1. . 5052.78	2. . 4521.48	3. . 3713.42
7. . 5.22	4. . 2871.12	5. . 1811.10
5058.00 = Σ	6. . 651.88	5554.52
	8044.48	2
	4	11109.04 = 2 *s*
	32177.92 = 4 S	

and since $\frac{i}{3} = \frac{2}{3}$, the sections here being now supposed to be two feet apart, we shall have

$$(\Sigma + 4\,\text{S} + 2\,s)\,\frac{i}{3} = (5058.00 + 32177.92 + 11109.04) \times \frac{2}{3} = 32229.97,$$

which is the amount of the moment in the fore body.

MOMENTS IN THE AFTER BODY.

Extreme Products.	Even Products.	Odd Products.
1. . . . 0.00	2. . . . 39.93	3. . . . 67.05
7. . . . 0.44	4. . . . 69.77	5. . . . 41.43
0.44 = Σ	6. . . . 14.18	108.48
	123.88	2
	4	216.96 = 2 *s*
	495.52 = 4 S	

and since $\frac{i}{3} = 0.61$, we shall have

$$(\Sigma + 4S + 2s)\frac{i}{3} = (0.44 + 495.52 + 216.96) \times 0.61 = 434.8812,$$

which is the value of the moment in the after body.

(152.) Now, since the moments in the middle and fore body are to be regarded as *positive*, and that in the after body as *negative*, we shall have

Moments in the middle body	=	+ 622325.025
Moments in the fore body	=	+ 32229.970
		+ 654554.995
Moment in the after body	=	− 434.8812
Hence whole moment of the immersion	=	+ 654120.1138

And since the solid content of the immersion has been found to be 7860.9703, we shall have

Position of centre of gravity of immersed volume before section 1.

$$\frac{M}{D} = \frac{654120.1138}{7860.9703} = 83.21 \text{ feet},$$

which is the distance of the centre of gravity of the immersed volume before section 1 of the middle body.

(153.) A similar mode of proceeding must be pursued for finding the distance forward of the Emersions Centre of Gravity.

Moments of the Middle Body.

Extreme Products.	Second Class of Products.	Third Class of Products.
1..0000.00	4.. 716.22	2.. 155.94
28..3947.94	7..1778.40	3.. 412.80
3947.94 = S	10..2792.34	5..1097.52
	13..3774.24	6 .1152.00
	16..4717.80	8..2128.14
	19..5661.36	9..2463.84
	22..6478.92	11..3145.20
	25..6406.56	12..3159.72
	32325.84	14..4088.76
	2	15..4103.28
	64651.68 = 2P	17..5032.32
		18..5346.84
		20..5962.06
		21..6266.40
		23..6553.80
		24..6683.34
		26..6058.50
		27..5260.32
		69969.78
		3
		209909.34 = 3Q

and since $\frac{3i}{8} = 2.25$, we shall have

$$(S + 2P + 3Q)\frac{3i}{8} = (3947.94 + 64651.68 + 209909.34) \times 2.25 = 626645.16,$$

which is the moment of the middle body.

Moments in the Fore Body.

Extreme Products.	Even Products.	Odd Products.
1..3947.90	2..3353.80	3 .2778.84
7.. 21.05	4..2027.76	5..1246.10
3968.95 = Σ	6.. 460.96	4024.94
	5842.52	2
	4	8049.88 = 2s
	23370.08 = 4S	

and since $\frac{i}{3} = \frac{2}{3}$, we shall have

$$(\Sigma + 4S + 2s)\frac{i}{3} = (3968.95 + 23370.08 + 8049.88) \times \frac{2}{3} = 23592.61,$$

which is the amount of the moment in the fore body.

Moments in the After Body.

Extreme Products.	Even Products.	Odd Products.
1...0.00	2...25.71	3 ..32.27
7...2.18	4...39.88	5...26.20
2.18 = Σ	6...11.25	58.47
	76.84	2
	4	116.94 = 2s
	307.36 = 4S	

and since $\frac{i}{3} = 0.61$, we shall have

$$(\Sigma + 4S + 2s)\frac{i}{3} = (2.18 + 307.36 + 116.94) \times 0.61 = 260.1528,$$

which is the value of the moment in the after body.

(154.) Two of these moments being positive, and the remaining one negative, we shall have

Moments in the middle body.	=	+ 626645.16
Moments in the fore body	=	+ 23592.61
		+ 650237.77
Moments in the after body.	=	− 260.1528
Hence whole moment of the emersion	=	+ 649977.6172

And since the solid content of the emerged volume = 7815.3119, we shall obtain

$$\frac{M}{D} = \frac{649977.6172}{7815.3119} = 83.17 \text{ feet},$$

which is the distance of the centre of gravity of the emerged volume before section 1 of the middle body.

Position of centre of gravity of emersion before section 1.

(155.) Since then the centres of gravity of the solids of immersion and emersion are found so very nearly in the same plane, differing only $\frac{4}{100}$ths of a foot, the construction, so far as regards this very important particular, may be esteemed correct.

(156.) Hence it follows, that the centre of gravity of the displacement is 0.95 feet before the mean distance of the centres of gravity of immersion and emersion; and the latter point 0.67 feet before the centre of gravity of the load water section.

If these centres be not found in some vertical plane, the ship will revolve round different axes.

(157.) Unless these centres of gravity be found as nearly as possible in the same transverse vertical plane, a ship is liable to revolve round different horizontal axes, producing irregular motions and impulses,—circumstances by no means to be desired. Nor should this property belong to one inclination only, but for every angle through which a vessel revolves. In the case

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of the Bulwark of 76 guns, the centre of gravity of her immersion at an angle of ten degrees' inclination, was only six inches in a fore and aft direction from the centre of gravity of the emersion, her character for regular and easy motion being of the best kind. In some other cases, however, where ships have been remarked for their uneasy motion, as to this diagonal pitching, these centres have been removed from the same plane three or four feet. According to Mr. Morgan this very important principle was first attended to in the construction of English ships.

Stability.

Stability.

(158.) The question of stability is divided naturally into two branches, named Hydrostatic stability, or the stability of a floating body at rest, and Hydrodynamic stability, or the stability of a floating body in motion.

Necessity of investigating it in a very general point of view.

(159.) The Naval architect should investigate the subject in the most general point of view, and by making himself acquainted with the singular relations which its application to bodies of different forms disclose, be enabled to investigate with confidence the stability of a ship of any kind, whether destined for commerce or the purposes of war.

Relation between immersed and whole floating body.

(160.) A slight acquaintance with Hydrostatics will convince us that a relation exists between the part of a floating body immersed in the sea, and the whole amount of its magnitude, dependent on the relative specific gravities of the fluid and solid mass. A body may, indeed, be immersed in a fluid in many different ways so as to preserve this relation entire, but there may not be one position in which it will permanently rest; nor can a state of quiescence be at any time obtained, until the vertical lines which pass respectively through the centres of gravity of the whole body and its immersed volume completely coincide.

Three kinds of equilibrium: Stability, Instability,

(161.) A floating body assumes three kinds of equilibrium when these centres of gravity are in the same vertical line: 1st, *the equilibrium of stability*, or that in which the solid permanently floats in a given position.

2dly, *the equilibrium of instability*, or that in which the body spontaneously oversets, unless sustained by some external force; and which kind of equilibrium takes place, when a needle or any other sharp pointed body is attempted to be raised on a smooth horizontal plane.

Indifference.

And 3dly, *the equilibrium of indifference*, occupying a kind of limit between the other two, when the solid rests on the fluid indifferent to motion, having no tendency to right itself when inclined, or in any way to increase its inclination.

The first most concerns the ship-builder.

(162.) The first of these conditions is that which most concerns the ship-builder thoroughly to understand. Among the great variety of bodies which permanently float on the surface of a fluid, experience tells us there are some more easily inclined from a quiescent position than others. Many bodies, after undergoing an inclination, return to their original positions with greater readiness and power than others; and this is particularly observable among ships at sea, where the same impulse of the wind produces a much greater inclination from a vertical position in one vessel than in another. Hence it is, that in order to form a due estimate of the resistance to inclination, and to be able to compute the absolute stability for different angles of inclination, Mathematicians have been induced to investigate rules, by which the stability of ships may be computed prior to their construction, when their dimensions and weight are known.

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Different ways in which the subject of stability has been computed. Investigations of Atwood.

(163.) There have been many beautiful essays published on the stability of floating bodies, some treating it theoretically and adorning the subject with the richest flowers of analysis, whilst others have aimed at a more practical character. The name of Atwood is rendered immortal in the annals of ship-building by two admirable Treatises on the stability of floating bodies, published in the *Philosophical Transactions* for 1796 and 1798. In these Papers he demonstrated, that a more accurate attention to the forms and dimensions of the solids immersed and emerged in consequence of the inclination was absolutely necessary; and leaving the consideration of infinitely small angles of inclination, which in so many cases leads to erroneous or inconclusive results, created a formula for finite angles of inclination, and which required as a fundamental condition, a rigid attention to the form of the body. Before entering on the consideration of this formula, we shall, however, briefly advert to a few remarkable particulars deduced by Mr. Atwood, respecting the equilibrium of floating bodies.

Positions of equilibrium deduced by Atwood.

(164.) In the first place, the total number of positions of equilibrium of a floating body, movable round a fixed axis, is in all cases an *even number;* and secondly, that the number of positions of equilibrium of stability, is equal to the number of positions of equilibrium of instability; so that in turning round an invariable axis, the body must alternately pass from a position of stability to one of instability. There must in every body be at least one position of equilibrium of absolute stability, and one of absolute instability.

Investigation of a square parallelopiped.

Numerical limits connected with its floating.

(165.) There are some relations depending, moreover, on the form and specific gravity of the body, which it is proper to advert to more particularly. If we take, by way of example, a square parallelopiped, floating freely on a fluid's surface, it will be found that so long as the specific gravity of the body is confined between the limits of zero and 0.211, the solid will permanently float on the fluid with a flat surface upward, parallel to the horizon. That when the specific gravity rises to any magnitude between the limits 0.211 and 0.25, the parallelopiped will float permanently with a flat surface upward, but inclined to the horizon at different angles, whose limits are zero, corresponding to the specific gravity 0.211, and 26° 34′ corresponding to the specific gravity 0.25. If, again, the specific gravity be found between the limits $0.25 = \frac{8}{32}$ and $\frac{9}{32}$, the parallelopiped will float with one angle only immersed beneath the surface, its diagonal being inclined to the vertical at various angles, depending on the specific gravity, the limits being 18° 26′, corresponding to the specific gravity $\frac{8}{32}$, and zero corresponding to the specific gravity $\frac{9}{32}$. As soon, however, as the specific gravity is increased beyond $\frac{9}{32}$, the solid will permanently float with one of its diagonals vertical, until the specific gravity reaches the limit of $\frac{23}{32}$. If again the specific gravity be augmented to any quantity between $\frac{23}{32}$ and $\frac{24}{32}$, the floating body will repose with its diagonal variously inclined, the limits being zero, corresponding to the spe-

cific gravity $\frac{23}{32}$, and 18° 26′ corresponding to the specific gravity $\frac{24}{32}$, three angles of the solid being in this case immersed beneath the fluid's surface. If, moreover, the specific gravity be augmented to a quantity between the limits $\frac{24}{32}$ and 0.789, the solid will float with a flat surface upward, inclined to the horizon at sundry angles depending on the specific gravity, the limiting angles being 26° 34′, corresponding to the first specific gravity $\frac{24}{32}$, or 0.75, and zero corresponding to the other specific gravity 0.789. Finally, when the specific gravity reaches a magnitude between the limits of 0.789 and unity, the assumed specific gravity of the fluid, the solid will float permanently with a flat surface parallel to the horizon.

(166.) Hence we infer, that while the square parallelopiped floating on the fluid's surface, has revolved completely round its longer axis, or through 360°, it has passed through either sixteen or eighteen positions of equilibrium. When the specific gravity is found between the limits 0.211 and 0.281, or between 0.719 and 0.789, the number of those positions will be sixteen, eight of which are positions of permanent, and the remaining eight of unstable equilibrium; the two kinds of equilibrium succeeding each other alternately, as the solid revolves. In case the specific gravity should be of any value not included within these limits, the solid in completing its rotation will pass through eight positions only of equilibrium, four of which are of permanent and four of unstable equilibrium.

Important for the young Naval architect to pursue this subject.

(167.) A number of singular properties might be given depending on the forms of bodies and their different specific gravities, and which it would be useful for the young Naval architect to investigate; but our limits will only permit us to refer to one or two. In the case of a cylinder placed on a fluid with its axis vertical, if the diameter of the base has to the axis a greater ratio than $\sqrt{2}:1$, no value can be given to the solid's specific gravity, which will cause it to float in a state of insensible equilibrium; or in other words, there is no specific gravity separating the cases in which the cylinder will float permanently, from those in which it will overset when the axis is placed vertically. The cylinder under these circumstances must always float permanently with its axis vertical. When, however, the diameter of the base has to the length of the cylinder, a less ratio than $\sqrt{2}:1$, two values of the specific gravity may be found, which form limits to the cases in which the solid floats with stability or oversets. If the specific gravity be given, the relation of the cylinder's length to the diameter of the base may be fixed which limits the cases of stability or instability of floating with the axis vertical. If, for example, the specific gravity be 0.75, and the diameter of the base has a greater ratio to the axis than $\sqrt{\frac{3}{2}}:1$, the cylinder will float permanently with its axis vertical; but if the ratio be less, the cylinder will overset.

Some instances.

(168.) If we take the case of a parabolic conoid,—a body connected with the immortal name of Archimedes, we shall find in the first place that when the axis is to the parameter in a less ratio than 3 : 4, no specific gravity can be found which will make the solid float in the equilibrium which is a limit between the stability and instability of floating. Secondly, that if the specific gravity of the solid bears a g to that of the fluid, than that which the s the difference between the axis and three-fourths parameter has to the square of the axis, when tha is placed vertically, the solid will float with stability that position. Thirdly, that if the specific gravity of th solid has a less ratio to the specific gravity of the fluid than that which the square of the above difference has to the square of the axis, the solid will overset when placed on the fluid with its axis vertical, and will settle permanently with its axis inclined to the vertical line. If the specific gravity of a parabolic conoid be less than the limit just referred to, and the axis be to the parameter in a greater ratio than 6 to 8 and less than 15 to 8, it will float permanently on the fluid with its axis inclined to the horizon, and with its base wholly visible above the surface. These beautiful properties we owe to that admirable analysis, which, in the hands of Archimedes, was cultivated with such transcendent success. Too much neglected by the moderns, it is refreshing to turn occasionally to these splendid remains of ancient genius. The investigations of Archimedes are contained in the second book of his tract, *De iis quæ in humido vehuntur.*

Tabular results of the properties of different bodies.

(169.) In order to place before the young ship-builder a few connected results on this interesting and important subject, we throw into the next Table Mr. Atwood's comparative stabilities of several bodies. Some elements, it will be perceived, are adopted by him as common, such as the breadth of the water section denoted by 100, the distance of the centres of gravity of the entire body, and of the immersed volume, represented by 13, the area of the section of the displaced volume denoted by 3600, and the angle of inclination 15°. From these assumptions he deduces the numerical values recorded in the two last columns.

Form of the Body.	Breadth of the Water Section.	Distance of the Centres of Gravity of the whole Body, and the immersed Volume	Area of the Section of the displaced Volume.	Angle of the Body's Inclination from the Perpendicular.	Numerical Value of G Z, or the Measure of the Body's stability.	Comparative Measure of the Weight, or Influence acting on the Sides of the Body at the mean distance of 30 from the Axis in Tons.
Sides of the vessel parallel to the plane of the masts above and below the water section.	100	13	3600	15°	2.84	56.8
Sides of the vessel above the water section projecting outwards 15°, and parallel to the masts below the same section	100	13	3600	15°	3.21	64 2
Sides of the vessel above the water section, inclining inwards 15°, and parallel to the masts below the same section.	100	13	3600	15°	2.53	50.6

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TABLE *continued.*

Form of the Body.	Breadth of the Water Section.	Distance of the Centres of Gravity of the Whole Body, and the immersed Volume.	Area of the Section of the displaced Volume.	Angle of the Body's Inclination from the Perpendicular.	Numerical Value of G Z, or the Measure of the Body's stability.	Comparative Measure of the Wind's influence acting on the Sails of the Body at the mean distance of 50 from the Axis, in Tons.
Sides of the vessel above and below the water section inclining outwards 15°.	100	13	3600	15°	3.59	71.7
Sides of the vessel above and below the water section inclining inwards 15°.	100	13	3600	15°	2.21	44.2
Sides of the vessel forming an isosceles wedge at an angle of 30°, its vertex immersed in the water.	100	13	3600	15°	2.86	57.0
Sides of the vessel forming an isosceles wedge at an angle of 60°, its vertex immersed in the water.	100	13	3600	15°	2.92	58.4
Sides of the vessel forming an isosceles wedge at an angle of 30°, its vertex above the water.	100	13	3600	15°	2.86	57.0
Sides of the vessel above the water section parallel to the masts, and inclining outwards 15° below.	100	13	3600	15°	3.21	64.2
Sides of the vessel above the water section parallel to the masts, and inclining inwards 15° below.	100	13	3600	15°	2.53	50.6
Sides of the vessel forming the uniform surface of a cylinder.	100	13	3600	15°	2.63	52.5
Sides of the vessel formed by arcs of a conic parabola.	100	13	3600	15°	2.81	52.8

(170.) The numbers which give the measures of the comparative stabilities afford some interesting materials for examination. A comparison of numbers 2 and 9, of 3 and 10, and of 6 and 8 disclose the remarkable fact, that whether the sides which spring from the water section, incline outwards *above*, or outwards *below*, the measure of the stability is the same; or whether the sides incline inwards *above*, or inwards *below*, the stabilities are still equal to each other. Whether the transverse section be, moreover, a rectangle, an isosceles wedge having its sides inclined to each other 30°, and with the vertex either above or below the water's surface; or whether the same section be a conic parabola, the measures of the stabilities are identical. The diligent inquirer may draw from the same Table other important information. Such are the curious and interesting results which even a brief examination of the subject affords. To the Papers of Atwood we would add the masterly Treatise of Dupin read before the Institute of France, and enriched by all the resources of Modern Geometry. It is a subject which the Naval architect should delight to dwell on, as one replete with the deepest interest, and lying at the foundation of his noble profession; which opens, moreover, an immense field for the finest applications of analysis, discloses relations of a singularly curious kind between forms and specific gravities, and in every point of view deserves an attentive philosophical examination.

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(171.) To those of our readers who may, however, be unable to follow Mr. Atwood through the analytical investigations necessary for computing these various stabilities, the same may be prosecuted experimentally, and a method for doing it may be seen in the *Annals of Philosophy* for 1824. A reference to Colonel Beaufoy's Tables will show how closely the results of experiment approximate to those of theory. Beaufoy's experiments.

(172.) But we must hasten to its application to ships, the main and essential object of this Treatise. It is a fundamental position that the resultant of the force which the water exerts in supporting a ship, and in resisting its tendency to heel, passes through the centre of gravity of the displacement, and that the direction of this effort is at right angles to the water's surface. It is for this reason a vessel, free and at rest, must have its centre of gravity in the resultant of the force of the water which supports it. When the ship heels, there is a tendency arising from the vertical pressure of the fluid acting upwards on the side of the vessel which is most immersed in the fluid to restore it to the position it had when at rest. The amount of this force is to be regarded as the measure of the stability. Application of the subject to ships.

(173.) Whenever a ship is inclined in the sea from an upright position, a prismatic solid is emerged on one side, to be denoted in the present investigation by E, and another prismatic solid immersed on the other, which we shall represent by I. These two solids, however dissimilar they may be from the peculiar figure of the ship, must of necessity be equal, the volume of the displacement remaining unaltered. The solids, moreover, being formed by the mutual intersection of two planes, one of which is the load water plane when the ship is floating upright, and the other a load water plane when she is inclined, the intersection must of necessity be a right line. From the circumstances, also, which influence the motion of the ship, this line must, moreover, be parallel to the axis of rotation, which is a right line passing through the centre of gravity of the vessel from head to stern. Let the line separating the immersion from the emersion be therefore denoted by x. Let G (pl. i. fig. 5) also be the centre of gravity of the whole ship, F that of its displacement when the ship floats upright, and Q the representative of the same point when the ship is laterally inclined. Let Q T V M Solids of immersion and emersion produced by the inclination of the ship. Investigation

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be a vertical line passing through the centre Q; and through F and G draw F T and G V at right angles to Q M, and through G draw G O parallel to Q M, intersecting F T in O.

(174.) Since, by the heeling of the ship, the volume E is taken from the displacement on the one hand, and I, which is equal to it, is added to the displacement on the other, the bulk of each volume being supposed to be concentrated in its centre of gravity, the former volume may be conceived to be transferred to I. The horizontal distance of the centres of gravity of the two volumes being denoted by b, the moment resulting from the translation of E will be b E, or b I.

(175.) Now when by the action of the wind the ship is made to heel through the angle A S a, or its equal F G O, the buoyant power of the fluid is transmitted upwards through the line Q M, with a force equivalent to the weight of the ship, or its equal the displacement D. The effort, therefore, made to right the ship, or to make it turn round a longitudinal axis passing through G, is proved by Atwood to be

$$\mathrm{D} \times \mathrm{GV} = \mathrm{D} \times \mathrm{FT} - \mathrm{D} \times \mathrm{FO}.$$

And since D × F T is the horizontal moment of the displacement in consequence of the removal of E to I, it is equal to the horizontal moment of E, that is to b I. Hence the preceding expression becomes

$$\begin{aligned} \mathrm{D} \times \mathrm{GV} &= b\mathrm{I} - \mathrm{D} \times \mathrm{FO} \\ &= b\mathrm{I} - \mathrm{D} \times \mathrm{FG} \times \sin \mathrm{FGO}. \end{aligned}$$

And if we represent F G by a, and the sine of the inclination of the vessel, or F G O, by s, we shall obtain the general formula

Formula of Atwood for stability.

$$\mathrm{D} \times \mathrm{GV} = b\mathrm{I} - \mathrm{D}as \ldots\ldots (\mathrm{I.})$$

(176.) This theorem, which is due to Atwood, enables us to find the stability of a floating body, whether that body be symmetrical with regard to the axis of motion, as is always the case in a ship, or whether symmetry of form does not exist, or the body be homogeneous, or the contrary. It is from this formula that Atwood derived the various positions of the floating parallelopiped before alluded to.

(177.) The line separating the volumes I and E must evidently be a right line, being formed by the intersection of two planes, that of the load water line when the ship is upright, and that of the load water line when the ship is inclined. This line, moreover, must be parallel to the axis of rotation, or to a right line passing through the centre of gravity of the ship, from head to stern. Let therefore the line separating the immersion from the emersion be denoted by x, and a longitudinal plane be supposed to pass through it, perpendicular to the water's surface. Suppose also Z to denote any section A S a of the solid I, perpendicular to x, and let z be the corresponding section B S b of the emerged solid E. Moreover let W, w be the horizontal distances of the centres of gravity of the sections Z and z from this longitudinal vertical plane. Then by the ordinary principles of Mechanics, we shall obtain

$$\frac{\int \mathrm{ZW}\,dx}{\mathrm{I}}$$

for the horizontal distance of the centre of gravity of the immersed solid I from that plane, and

$$\frac{\int z w\,dx}{\mathrm{E}}$$

for the horizontal distance of the centre of gravity of the emerged solid E from the same plane. Hence

$$b = \frac{\int \mathrm{ZW}\,dx}{\mathrm{I}} + \frac{\int z w\,dx}{\mathrm{E}};$$

or since by the conditions of a floating body I = E, we shall further obtain

$$b = \frac{\int \mathrm{ZW}\,dx + \int z w\,dx}{\mathrm{I}},$$

or $$b\mathrm{I} = \int \mathrm{ZW}\,dx + \int z w\,dx.$$

Consequently the general expression denoted by (I.) will become

Another expression of the same.

$$\mathrm{D} \times \mathrm{GV} = \int \mathrm{ZW}\,dx + \int z w\,dx - \mathrm{D}as \ldots. (\mathrm{II.})$$

which is another expression for the stability of a ship.

(178.) This formula is susceptible of some modifications by supposing the heeling of the vessel to be evanescent. In this case by denoting the half breadth of the ship at the water' surface by y, we shall have

$$\mathrm{Z} = z = \frac{y \times sy}{2} = \frac{sy^2}{2},$$

and $$\mathrm{W} = w = \frac{2}{3}y;$$

and the general formula (II.) becomes

Another form for the preceding formula.

$$\mathrm{D} \times \mathrm{GV} = \frac{2}{3}\int sy^3\,dx - \mathrm{D}as \ldots. (\mathrm{III.})$$

If the indefinitely small angle be regarded as constant, this last expression for the stability becomes

$$\frac{2}{3}\int y^3\,dx - \mathrm{D}a.$$

When the displacement is given, the stability is measured by

$$\frac{\frac{2}{3}\int y^3\,dx}{\mathrm{D}} - a,$$

which is the case when two ships of equal displacement are inclined at some small constant angle.

Formula for the metacentre.

The function $$\frac{\frac{2}{3}\int y^3\,dx}{\mathrm{D}}$$

is the height of what is commonly called the metacentre above the centre of gravity of the displacement. In this case the stability will be measured by the height of the metacentre above the centre of gravity of the ship.

(179.) In any case where the centre of gravity of displacement might coincide with the centre of gravity of the ship, the value of a becomes zero, and the stability at any small angle of inclination will be

Formula for any small angle of inclination.

$$\frac{2}{3}\int sy^3\,dx,$$

and supposing this small angle to be constant, we shall have

$$\frac{2}{3}\int y^3\,dx \ldots\ldots\ldots (\mathrm{IV.})$$

The latter formulæ must be employed with caution.

(180.) These latter formulæ, however, must be employed with caution, and in no case can they be relied on as measures of the stability, excepting at the very instant when a ship begins to heel. In the case of an

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ordinary inclination of five or ten degrees, the relation of the stabilities in two separate cases might be very different from what the formula (IV.) would give, when the centres of gravity of the whole ship and the displacement coincide; or what may be derived from the preceding formula (III.) when the centre of gravity of the ship is higher than that of the displacement. For in either case the values of W, w, might neither be equal to each other, nor to $\frac{sy^s}{2}$; and the values of Z and z may also very much differ from $\frac{2y}{3}$.

Example to prove the necessity of caution.

(181.) By way of illustration, suppose two vessels, A and B, figs. 6 and 7, to be so constructed, as to have identical load water lines, and the centres of gravity of the whole ship and the displacement to coincide; the sides of one of the vessels falling out above and below the water's surface, and the sides of the other falling in. Now, although the most ordinary mechanic must at once perceive that the stabilities of these bodies are not the same; and that the same impulse of the wind on equal masts and sails may in the two cases produce very different effects,—in one instance producing perfect security, and in the other extreme danger,—yet according to formula (IV.) the stability of each will be the same. Thus may the Naval Architect who is really desirous of advancing his art, draw from these analytical forms, motives for caution; and, moreover, learn, that although formulæ may sometimes be sanctioned by high names, and for a long time be current in the world, yet unless founded on legitimate facts and on that unyielding Geometry which allows nothing to escape its power, they ought at once to be rejected, or received only as approximations, until others founded on better principles can be found.

A single computation of the stability at one angle not sufficient.

(182.) It is not a single computation of the stability at one given angle, that can satisfy the desires of the scientific ship-builder. It must be found for three or four angles of heeling, as 2°, 5°, 7°, 9°, &c., in order to satisfy him whether the vessel he is about to construct has a sufficient stiffness at each successive angle, and whether at the same time she performs her motion of rolling with ease. In such a case some fine and approved model of the same class is commonly selected as a standard, in order to assist the constructor in his conceptions. A Naval Architect well acquainted with the details of his profession, may even from the principal dimensions and form of the sides between wind and water, make a tolerable estimate of the vessel's stability, by knowing the principal dimensions and form of the sides between wind and water.

To deduce from formula (II.) the actual stability.

(183.) But to deduce at once from the general formula

$$\int W Z\, d x + \int w z\, d x - D a s$$

the actual stability of a vessel, some angle of heeling, or inclination must be fixed on. Suppose, for example, it be 9°, and that an inclined load water plane be drawn, forming transversely with the horizontal plane of the same kind an angle equivalent to this quantity. In the great majority of cases, the solids of immersion and emersion formed by these planes will not be equal, their common intersection, excepting in particular constructions, falling on the lee side of the middle of the load water line. Hence an interval of $\frac{2}{10}$ or $\frac{3}{10}$ths of a foot is assumed on one side of the middle point of the load water line on the body plan, for the intersection of the two planes.

How the solids of emersion and immersion may be computed.

(184.) To compute the solids of emersion and immersion recourse must be had to the sectorial areas formed by the vertical sections of the body with the solids here adverted to. Each of these sectorial areas may be regarded as made up of a triangle and a curvilineal space, the latter being without sensible error regarded as a parabolic area. Having computed the whole of the sectorial areas, the actual solidities of immersion and emersion must be computed by the proper formulæ.

What must be done if those solids are not found to be equal.

(185.) If the results of these computations should prove the solidities of immersion and emersion to be unequal, some other point must be assumed for the intersection of the inclined and load water lines, and the preceding computation repeated until the two solidities are found equal. To assist us in determining this point, let Δ represent the computed difference of the solids of immersion and emersion, and a the area of the inclined load water plane. Moreover, let x be the perpendicular distance of the true inclined load water line from that just assumed. Then it is manifest, that without any very sensible error $a x = \Delta$, and consequently, $x = \frac{\Delta}{a}$, both of which functions are known. Hence the value of the fraction $\frac{\Delta}{a}$ being set off at right angles to the load water line first assumed, will give the position of the true one, as required.

When an equality is found between them how the stability may be computed.

(186.) Supposing, therefore, the position of the true inclined load water line to be at length attained, we may proceed to the final calculation of the stability. The integral of the function $W Z\, d x$ may be obtained by means of the sectors already alluded to. The different values of Z and z necessarily result from that process of computation, and the values of W and w may be found as follows. Suppose S B D, fig. 8, to represent one of the sectors, S D the upright load water line, and S B that which is inclined. Joining D B will divide the sector into the triangle and supposed parabolic area before alluded to. Bisect B D in E, draw E C perpendicular to B D, and make E F equal to two-fifths of it. From E and F let fall E G and F H at right angles to S B. Then will two-thirds of S G be the distance of the centre of gravity of the triangle S D B from the point S, measured on the surface of the water; and S H will be the distance from the same point of the centre of gravity of the curvilineal area D B C. Hence

$$\frac{2}{3} SG \times SBD + SH \times BCD$$

will give the value of W Z for this sector. And thus may the value of W Z be found for every sector. The application of one of the formulæ for equidistant ordinates hence determines the integral of $W Z\, d x$.

(187.) A like method is pursued in determining the integral of the same function when its elements are made to represent the more curved parts of the immersion that lie near the stern post and stern. In a similar manner the value of $\int w z\, d x$ may be found.

(188.) With regard to the remaining function $D a s$, the value of the displacement D has been already computed, and s is known from the fixed inclination of the vessel. The element a, depending on the true position

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of the centre of gravity of the vessel, can only be found by rigorous calculations, which we shall hereafter explain, or by reference to another ship of the same kind. Hence the value of all the functions constituting the second member of the equation

$$D \times G V = \int Z W\, d x + \int z\, w\, d x - D\, a s$$

are known, and thus the true measure of the stability is obtained. Let it be borne, however, in mind, that tedious as the processes of calculation may be found, the constructor must repeat them, until he finds at every reasonable inclination, that the stability is neither too small nor too great, and that the changes produced by rolling are such as shall satisfy both him and the gallant men who may hereafter navigate the vessel on the sea.

Actual computation.

(189.) The first step in the computation we shall illustrate is that of the solidities of immersion and emersion. Each of these will be divided as before into the middle body, the fore body, and the after body, these several parts being calculated by means of the proper formula.

To find the Content of the Immersion when heeled to 9°.

To find the content of the immersion.

AREAS OF THE SECTIONS IN THE MIDDLE BODY.

Extreme Areas.	Second Class of Areas.	Third Class of Areas.
1..24.47	4..42.16	2..33.23
28..31.19	7..46.75	3..38.46
55.66 = S	10..49.61	5..44.40
	13..50.31	6..45.79
	16..50.31	8..47.87
	19..49.87	9..49.37
	22..49.67	11..50.06
	25..46.67	12..50.31
	385.35	14..50.31
	2	15..50.31
		17..50.18
	770.70 = 2 P	18..49.94
		20..49.75
		21..49.72
		23 .49.36
		24..48.56
		26..43.62
		27..39.12
		840.36
		3
		2521.08 = 3 Q

and since $\frac{3\,i}{8} = 2.25$, we shall have

$$(S + 2\,P + 3\,Q)\frac{3\,i}{8} = (55.66 + 770.70 + 2521.08) \times 2.25 = 7531.74,$$

which is the solid content in the middle body.

AREAS OF SECTIONS IN FORE BODY.

To find in the next place the solidity of the fore body we shall employ the formula

$$(\Sigma + 4\,S + 2\,s)\frac{i}{3}.$$

Extreme Areas.	Even Areas.	Odd Areas.
1..31.19	2..27.57	3..22.37
7.. 0.03	4..17.09	5..10.83
31.22 = Σ	6.. 3.79	33.20
	48.45	2
	4	66.40 = 2 s
	193.80 = 4 S	

and since $\frac{i}{3} = \frac{2}{3}$, the sections here being now supposed two feet apart, we shall have

$$(\Sigma + 4\,S + 2\,s)\frac{i}{3} = (31.22 + 193.80 + 66.40) \times \frac{2}{3} = 194.28,$$

which is the solid content in the fore body.

AREAS OF SECTIONS IN AFTER BODY.

In like manner, by applying the same formula to the after body, we shall have

Extreme Areas.	Even Areas.	Odd Areas.
1..24.47	2..22.93	3..18.32
7.. 0.04	4..12.71	5.. 5.66
24.51 = Σ	6.. 1.55	23.98
	37.19	2
	4	47.96 = 2 s
	148.76 = 4 S	

and since $\frac{i}{3} = 0.61$, we shall have

$$(\Sigma + 4\,S + 2\,s)\frac{i}{3} = (24.51 + 148.76 + 47.96) \times 0.61 = 134.9503$$

for the solidity in the after body. Hence the total amount of the solid of immersion will be 7860.9703 cubic feet.

To find the Content of the Emersion when heeled to 9°.

To find content of the emersion.

(190.) By a similar process of computation we shall obtain the solidity of emersion.

AREAS OF SECTIONS IN MIDDLE BODY.

Extreme Areas.	Second Class of Areas.	Third Class of Areas.
1..17.19	4..39.79	2..25.99
28..24.37	7..40.40	3..31.34
41.56 = S	10..51.71	5..45.73
	13..52.42	6..48.40
	16..52.42	8..50.67
	19..52.42	9..51.33
	22 .51.42	11..52.42
	25..44.49	12..52.42
	394.07	14..52.42
	2	15..52.42
		17..52.42
	788.14 = 2 P	18..52.42
		20..52.29
		21..52.22
		23..49.65
		24..48.43
		26..40.39
		27..33.72
		847.68
		3
		2543.04 = 3 Q

and since $\frac{3\,i}{8} = 2.25$, we shall have

$$(S + 2P + 3Q)\frac{3\,i}{8} = (41.56 + 788.14 + 2543.04)$$

$$\times\ 2.25 = 7588.665$$

for the content in the middle body.

Areas of Sections in the Fore Body.

Extreme Areas.	Even Areas.	Odd Areas.
1..24.37	2..20.45	3..16.74
7.. 0.12	4..12.07	6.. 7.33
24.49 = Σ	6.. 2.68	24.07
	35.20	2
	4	48.14 = 2 s
	140.80 = 4 S	

and since $\frac{i}{3} = \frac{2}{3}$, the sections here being now supposed to be two feet apart, we shall have

$$(\Sigma + 4\,S + 2\,s)\frac{i}{3} = (24.49 + 140.8 + 48.14)$$

$$\times \frac{2}{3} = 142.29,$$

which is the solid content in the fore body.

Areas of Sections in After Body.

In like manner for this portion of the emerged volume we shall have

Extreme Areas.	Even Areas.	Odd Areas.
1..17.19	2..14.05	3..10.16
7.. 1.98	4.. 7.63	5.. 3.58
19.17 = Σ	6.. 1.23	13.74
	22.91	2
	4	27.48 = 2 s
	91.64 = 4 S	

and since $\frac{i}{3} = 0.61$, we shall have

$$(\Sigma + 4\,S + 2\,s)\frac{i}{3} = (19.17 + 91.64 + 27.48) \times 0.61$$

$$= 84.3569$$

for the solidity in the after body.

Hence the whole amount of the solid emerged by the heeling of the ship 9°, will be 7815.3119 cubic feet.

Computation of the function $\int Z\,W\,d\,x$.

(191.) Let us in the next place endeavour to obtain the value of $\int Z\,W\,d\,x$ for the three parts into which the immersed part is divided.

The values of Z W in the IMMERSION of the MIDDLE BODY are obtained as follows:

1..282.69	4..641.25	2..447.46
28..400.56	7..750.05	3..558.52
683.25 = S	10..803.92	5..691.93
	13..815.02	6..726.73
	16..815.02	8..773.11
	19..807.98	9..799.13
	22..801.99	11..811.13
	25..738.91	12..815.02
	6174.14	14..815.02
	2	15..815.02
	12348.28 = 2P	17..812.92
		18..809.03
		20..805.99
		21..803.04
		23..799.23
		24..783.74
		26..663.97
		27..562.86
		13293.85
		3
		39881.55 = 3 Q

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and since $\frac{3\,i}{8} = 2.25$, we shall have

$$(S + 2\,P + 3\,Q)\frac{3\,i}{8} = (683.25 + 12348.28$$

$$+ 39881.55) \times 2.25 = 119054.43,$$

which is the value of the integral $\int Z\,W\,d\,x$ in the MIDDLE BODY.

(192.) In the same manner, to obtain the values of Z W in the FORE BODY, we shall have

1..400.56	2..297.42	3..173.18
5.. 0.01	4.. 55.19	2
400.57 = Σ	352.61	346.36 = 2 s
	4	
	1410.44 = 4 S	

and since $\frac{i}{3} = 1$, we shall have

$$(\Sigma + 4\,S + 2\,s)\frac{i}{3} = (400.57 + 1410.44 + 346.36)$$

$$\times\ 1 = 2157.37$$

for the value of the integral $\int Z\,W\,d\,x$ in the FORE BODY.

(193.) So also for the values of Z W in the AFTER BODY, we shall obtain

1..282.69	2..254.53	3..181.65
7.. 0.01	4..106.70	5.. 37.29
282.70 = Σ	6.. 4.60	218.94
	365.83	2
	4	437.88 = 2
	1463.32 = 4 S	

and since $\frac{i}{3} = 0.61$, there results

$$(\Sigma + 4\,S + 2\,s)\frac{i}{3} = (282.7 + 1463.32 + 437.88)$$

$$\times\ 0.61 = 1332.179$$

for the integral of $\int Z\,W\,d\,x$ in the AFTER BODY.

Hence the value of $\int Z\,W\,d\,x$ for the whole IMMERSED VOLUME will be 122543.979.

(194.) Proceeding in the same manner for the EMER-

SION, we shall obtain the following results for the values of $z\,w$ in the MIDDLE BODY.

1 . . 164.16	4 . . 580.42	2 . . 305.97
28 . . 280.47	7 . . 804.99	3 . . 461.88
444.63 = S	10 . . 869.36	5 . . 708.63
	13 . . 889.99	6 . . 771.27
	16 . . 890.09	8 . . 835.98
	19 . . 885.08	9 . . 857.22
	22 . . 858.23	11 . . 881.91
	25 . . 690.65	12 . . 888.67
	6468.81	14 . . 890.09
	2	15 . . 890.09
	12937.62 = 2 P	17 . . 889.72
		18 . . 887.48
		20 . . 883.61
		21 . . 880.69
		23 . . 819.02
		24 . . 778.57
		26 . . 591.53
		27 . . 457.05
		13679.38
		3
		41038.14 = 3 Q

and since $\frac{3\,i}{8} = 2.25$, we shall have

$$(\mathrm{S} + 2\,\mathrm{P} + 3\,\mathrm{Q})\frac{3\,i}{8} = (444.63 + 12937.62 + 41038.14) \times 2.25 = 122445.8775,$$

which gives the value of $\int z\,w\,d\,x$ in the MIDDLE BODY.

(195.) In like manner to obtain the values of $z\,w$ in the FORE BODY, there will arise

1 . . 280.47	2 . . 186.03	3 . . 99.04
5 . . 0.12	4 . . 30.47	2
280.59 = Σ	216.50	198.08 = 2 s
	4	
	866.00 = 4 S	

and since $\frac{i}{3} = 1$, we shall further obtain

$$(\Sigma + 4\,\mathrm{S} + 2\,s)\frac{i}{3} = (280.59 + 866.00 + 198.08) \times 1 = 1344.67$$

for the value of $\int z\,w\,d\,x$ in the FORE BODY.

(196.) And lastly, for the values of $z\,w$ in the AFTER BODY, there will be

1 . . 164.16	2 . . 121.42	3 . . 77.42
7 . . 0.12	4 . . 48.83	5 . . 22.55
164.28 = Σ	6 . . 3.15	99.97
	173.40	2
	4	199.94 = 2 s
	693.60 = 4 S	

and since $\frac{i}{3} = 0.61$, there will lastly arise

$$(\Sigma + 4\,\mathrm{S} + 2\,s)\frac{i}{3} = (164.28 + 693.60 + 199.94) \times 0.61 = 645.2702$$

Numerical value of this function.

for the value of $\mathrm{S}\,z\,w\,d\,x$ in the AFTER BODY.

(197.) Hence the value of $\int z\,w\,d\,x$ for the whole emerged volume will be 124435.8177.

Computation of the function $\mathrm{D}\,a\,s$.

(198.) Finally, to compute the value of the function $\mathrm{D}\,a\,s$, the amount of the displacement D has been found to be 104926.2, and s the natural sine of $9° = 0.15643$. Of the remaining element a it may be remarked that it is made up of two parts, one of which is the height of the centre of gravity of the vessel *above* the load water line, and the other is the distance of the centre of gravity of the displacement *below* the same line. The first of these quantities, by a comparison with another ship of the same kind, is found to be 0.93 feet, and the value of the latter we have calculated to be 7.56 feet. Hence $a = 0.93 + 7.56 = 8.49$ feet, and $\mathrm{D}\,a\,s = 393151.5104$, and the general expression

Whole value of the stability.

$$\mathrm{D} \times \mathrm{G\,V} = \int \mathrm{Z\,W}\,d\,x + \int z\,w\,d\,x - \mathrm{D}\,a\,s = 107628.2863,$$

which is the numerical measure of the stability at an inclination of 9°.

(199.) By some, the preceding computations may be regarded as tedious, and they may prefer Bouguer's formula $\frac{2}{3}\int y^3\,d\,x$ before alluded to, on account of its greater brevity; but let it be remembered, that no labour can be considered as too great, in order to secure to a ship of the humblest class the requisite stability. The history of ship-building unfortunately presents too many instances of ships having been constructed with insufficient stability.* M. Romme, for example, in his *Art de la Marine*, has adduced the remarkable instance of the French ship *Le Scipion* of 74 guns. As soon as this ship floated in deep water, it was immediately apparent that she wanted stability, and to ascertain it, the guns were run out on one side, and run in at the other. The vessel in consequence heeled 13 inches; and by adding the weight of the men to the same side, she was afterwards brought down 24 inches. A difference of opinion, it appears, existed among the Naval engineers as to the cause of this want of stability; and that the error was not accidental, but arose from some faulty principle of construction, may be inferred from the circumstance that the same defect existed in two other ships of war, *L'Hercule* and *Le Pluton*. The chief engineer asserted that the requisite stability might be imparted to *Le Scipion* by altering the quality and disposition of her ballast. The original amount of ballast had been 84 tons of iron and 100 tons of stone; and by the new arrangement these were to be augmented to 198 tons of iron and 122 tons of stone. But as a ship of war does not admit of any alteration in the amount of her displacement to compensate for the additional weight of ballast, on account of the necessity which exists of keeping her ports at a proper height above the water, the stock of water with which the ship had been previously supplied, was diminished by 136 tons, the excess of weight of the new ballast over the old. This arrangement must have had the effect of lowering the centre of gravity of the vessel, and thereby of increasing its stability; but on trial it was found not

Frequent instances of ships constructed with insufficient stability.

* Chapman remarks, that in the year 1628, when the Wasa of 80 guns, *half cartauers*, or 24-pounders, sailed from Skeppsholmen to Stockholm, with only the three topsails, in a light South-West wind, intended for an expedition to the Baltic, this ship did not proceed further than Blockhusudden, or about fifteen or sixteen cables' length from Skeppsholmen, when it upset, and sank ten fathoms, so that all below the main cross trees was under water.

The Stora Crona, Swedish ship of 126 guns, upset in 1676 in tacking. The cause assigned was, that this operation was not performed with the care which the crankness of the ship required.

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to be sufficient, the decrease in heeling, measured on the vessel's side, amounting only to four inches. Other ineffectual attempts were made, but the requisite stability was not obtained, until a sheathing was applied to the exterior sides of the vessel from four inches to one foot in thickness, throughout the whole extent of the water line, and extending 10 feet beneath it.

Proof of error of formula with evanescent angles.

(200.) This memorable example affords, therefore, a convincing proof that the formula sometimes employed to represent the stability, and limited to evanescent angles of inclination, cannot be relied on in any way. There can be no doubt that before a timber was laid, the stability had been in some way or other computed, yet no one suspected a defect in this important element until the vessel was actually floating in deep water; and as a proof that the real cause of the error was not known, recourse was had to a change of ballast; nor was it until other remedies had been unsuccessfully applied, that "the remedy," to adopt the remarkable words of Atwood, "was stumbled upon by accident, rather than adopted from any knowledge of the principles by which the application of it might have been directed." It was reserved for Atwood to show that "an error in the form of the sides of the vessel was the principal cause of the defective stability,"* and affords another example of the slow steps by which sound and substantial knowledge advances.

Effect of motion on the stability.

(201.) The change which takes place in the vertical pressure of the water in which the ship is immersed, when there is any relative motion existing between the ship and the water, must have an effect on the amount of the stability, on account of that vertical pressure affording a measure for the stability, when it is multiplied into the distance at which it acts from the longitudinal axis passing through the centre of gravity. So the altered circumstances of displacement which take place by a ship passing from salt to fresh water, altering in some degree the position of the centre of gravity of the immersed volume, must, in like manner, influence the stability.

Positions of the metacentre in different ships.

(202.) The point M, fig. 5, is called the metacentre, and is very often referred to in discussions on ship-building. In the British Navy the height of the metacentre above the surface of the water, using in the calculation the main breadths, is generally less than 6 feet, and is least in the largest ships. In 18-gun-brigs it is 5.5 feet, and such vessels are by no means deficient in stability. In frigates of 36 guns it is nearly 6 feet. In the Leopard, a fourth-rate, it is 4.2 feet. In third-rates it is from 4 to 5.5 feet nearly. In the Howe, a first-rate of 120 guns, it is 3.7 feet. Bouguer, in his *Traité du Navire*, remarks, that the metacentre was above the centre of gravity, in the frigate La Gazelle, 4 or 5 feet; in ships of 60 guns from 6 to 7 feet; in ships of 80 or 90 guns, from 4 to 5 feet; and in ships of 110 or 120 guns, sometimes as little as 2 feet.

* As an evidence that the defect of stability in *Le Scipion* did not arise from a want of breadth in the principal section of the vessel, M. Romme asserts, that other ships of the same force, *Le Magnifique, Le Sceptre, Le Minotaur, L'Intrepide*, had breadths the same or rather less than *Le Scipion*, and yet carried their sail perfectly well. The constructor doubtless thought to please his eye by altering in some way the external figure of the vessel, and, to satisfy a whim, sacrificed her security.

On the Centre of Gravity.

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(203.) A knowledge of the position of the centre of gravity of a ship is necessary in order to assist us in establishing a true measure for the stability, and likewise for enabling us to trace all the interesting phenomena connected with the pitching and rolling of a vessel. A rude approximation to the position of this point will by no means satisfy the present wants of Naval Architecture; and we are glad to perceive an increased anxiety on the part of our ship-builders, to arrive at more exact information respecting its very important properties.

Centre of gravity of a ship

(204.) There are many difficulties in the way of determining the centre of gravity of the hull alone, before any preparations are made for fitting it for sea, and for storing it with all the terrible apparatus of war. A knowledge of its true position under conditions like these leads to many interesting results; but the question rises immeasurably in importance when the vessel puts on all the pride and circumstance of war,—with her masts and yards and rigging, her guns and vast variety of stores,—and the bodies too of her crew, destined gallantly to defend her. If we direct our attention for a moment to the hull, we shall find, that though the powers of Geometry may enable us to fix with very great accuracy the position of this point, that no general conclusion could be deduced from the same, on account of the great diversity of form which even ships of the same class present. This would have an influence, were the hull alone to be considered; but the many altered circumstances which even the smallest change in the external figure produces in the masts and their accompaniments, and all the important considerations connected with stores and stowage, proves the utter impossibility of laying down any thing like a precise and definite rule respecting the position of this point.

Difficulties in the way of determining the centre of gravity.

(205.) Wherever the point under consideration is, however, situated, three rectangular coordinate planes may be supposed to pass through it, and to one only of these three can we assign a fixed and certain position. Every vessel, whatever may be her figure, and however whim and caprice* may influence the design, is necessarily, both as regards figure and stowage, divided into two parts by a vertical longitudinal plane passing through the middle of the keel. This partial symmetry of form fixes, therefore, the centre of gravity of a vessel with regard to its breadth.

Three coordinate planes may pass through it.

(206.) Another consideration which will enable us to fix the position of this point with regard to the length of the vessel, may be gathered from the hydrostatical principle, that the centre of gravity of the whole body and of the displaced volume must be in the same vertical line; and that as every vessel, when equipped, possesses a *given* displacement, it follows that the centre of gravity of this volume determines the centre of gravity of the whole ship, with regard to the length. Independently of this, however, it would be impossible to fix, *à priori*, a transverse plane, having the moleculæ on each side of it precisely similar and equal.

Position of this centre with regard to the length.

(207.) With regard to the depth of the vessel, a vague and uncertain conjecture has sometimes fixed it

With regard to the depth.

* The history of ship-building proves that it is not uncharitable to say, that whim and caprice *do* sometimes govern the designs of ships.

in the load water section; but this, which at most can only be true of a few ships, is much too uncertain to allow us to repose on it with any thing like confidence. Various experimental methods have been proposed to ascertain this, but there is no method like that which the theory of moments presents us with, by assuming a convenient horizontal plane, and dividing the integral of all the moleculæ constituting the vessel, by the weight of the vessel itself. Such of our readers as are conversant with the Theory of Mechanics,—and every ship-builder ought,—will remember, that if any number of particles p, p', p'', &c., be situated on one side of a plane given in position, at the distances x, x', x'', &c.; and any number of particles π, π', π'', &c., on the other, at the distances X, X', X'', &c., then will the distance of the common centre of gravity of all the particles from the assumed plane be represented by the general formula

Theory of moments.

$$\frac{p\,x + p'x' + p''x'' + \&c. - (\pi X + \pi' X' + \pi'' X'' + \&c.)}{p + p' + p'' + \&c. \ldots + \pi + \pi' + \pi'' + \&c.},$$

the point being found on one side or other of the assumed plane, according as $p\,x + p'x' + p''x'' + \&c.$ is *greater* or *less* than $\pi X + \pi' X' + \pi'' X'' + \&c.$

How the method of moments may be applied to it.

(208.) We regret that our limits will not permit us to exhibit the whole process of this calculation, and that we must confine ourselves to a general description of results. It is usual in a case of this sort to assume the water's surface as the given plane, and to throw all the weights, whether fixed or movable, into two classes, one of which shall have every individual centre of gravity *above* the plane of flotation, and the other *below*. In this way we shall obtain the weights of such parts of the lower masts as are above the plane of flotation, the top masts, the top gallant masts, and necessary appendages, together with the yards and bowsprits, and likewise the distances of the centres of gravity of the individual masses above the plane of flotation. The former results would be so many values of p, and the latter of x. These values multiplied together will give the amount of the moment $p\,x$. In like manner must the weight of all the standing and running rigging be obtained, together with the distances of their respective centres of gravity from the plane before alluded to. These results will give values for p' and x', and hence the amount of the moment $p'x'$. So also the same elements must be obtained for the cables, hawsers, &c., particular attention being paid to the place of their stowage. The sails also when furled on their respective yards, and the spare sails as they are stowed in the sail-bins. The guns also, forming so very important a part of the computation, must have their entire weights estimated, with all their appendages, and also with the greatest care have the distances of their centres of gravity calculated from the assumed plane, after making every proper allowance for the curvature of the decks. In like manner the moments of the anchors, taken in their proper places of stowage, the boats, the furniture of all kinds, the men's bedding, as stowed in the nettings, together with the entire moment of the men estimated at their quarters: all these, together with any other moment which our limited space prevents us from enumerating, when collected together, will give the sum of the moments *above* the water's surface.

Moments above plane of flotation.

Moments below plane of flotation.

(209.) In like manner, proceeding for the moments *below* the water's surface, a very important object is presented by the hull, separated as it is by the plane of flotation, into portions *above* and *below* the water's surface. To find this with precision, however, every bend of timber must be taken in succession, and, however tedious be the process, the keel, the planking, the riders, the beams, the decks, the knees, whether of iron or wood, the shelf pieces, water ways, and all the numerous parts constituting the hull,—each individual weight, with the corresponding distances of their centres of gravity from the plane of flotation, must be found to obtain the absolute moment of the hull. The water, whether contained in tanks or casks, must be computed with the same minute attention to accuracy; and so also must the wood and coals, as stowed in bulk. The specific gravity of each separate kind of provision must be found, and which, by knowing the bulk of the same, and the position of the centre of gravity, will furnish the moment desired. In the same manner, the wine and spirits as stowed in the spirit rooms, the beer, the purser's slops, and the men's chests must have their respective moments found. The shot also, the powder in the magazines, the boatswain's, gunner's, and carpenter's stores, as deposited in their respective store rooms, each and all of these must have their moments determined.

(210.) To obtain the moment of the ballast, its absolute weight must first be found. This may be computed by subtracting the absolute weight of all the preceding articles from the total displacement. To discover its centre of gravity, a plan of the intended stowage must be carefully prepared, and the position of this point thence carefully deduced. Its distance below the plane of flotation, multiplied into the weight of the ballast itself, will give the required momentum.

(211.) These different numerical results, applied in their proper order to the formula before given, will furnish the distance of the centre of gravity of the vessel from the plane of flotation; and which will either be above or below, according as the funcion $p\,x + p'x' + p''x'' + \&c.$ is greater or lesser than $\pi X + \pi' X' + \pi'' X'' + \&c.$

Results of two examples.

(212.) The heights of the centres of gravity of two ships of the line, determined by this method, were as follows: Bulwark of 76 guns, $\frac{7}{10}$ths of a foot above the load water section; Ajax of 74 guns, $\frac{6}{10}$ths of a foot above the load water section. We ought to know with certainty and precision the position of the centre of gravity of every ship. No amount of labour can be too great for determining this important element.

More convenient modes may be adopted.

(213.) It is necessary, however, to be able to arrive at a knowledge of the same by means more ready and practical than that here alluded to. Instead of estimating the separate parts, and computing the individual moments, it may be useful sometimes to take a vessel as a mass, and determine her centre of gravity in her entire state. A method of Chapman's was applied by Captain Hindmarsh and Mr. Morgan to the Scylla of 18 guns, which we shall briefly describe. The ship floated in harbour perfectly quiescent, having all her weights balanced equally on each side. A large graduated quadrant, having a plumb line attached to its centre, was fixed in the main hatchway. The situations of the different guns were marked on the deck. The guns were then moved in the same transverse lines to the other side. The shot and hammocks were also transposed to the inclined side, and the crew, which in the first place were equally distributed, were likewise disposed there. The distances which all the transferred weights had been moved were then measured, the separate amount of those weights being previously known.

Experimental method of Chapman's.

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Under these circumstances the inclination of the vessel was carefully measured and found to be 6° 20′.

Chapman's formula.

(214.) Chapman devised a formula, by which the centre of gravity of a vessel under these circumstances might be obtained. Let each weight that has been transferred be multiplied by the distance it has been moved, and let the total amount of these momenta be divided by the total sum of the weights moved, and let N P, fig. 5, drawn at right angles to M F, be made equal to this quantity. Through N draw N Q parallel, and through P draw P Q perpendicular to $a\,b$. Then, by putting W to represent the total transferred weights in cubic feet of sea water, we shall obtain from the principles of Mechanics the equation

$$W \times NQ = D \times GV,$$

arising from the necessary equality existing between the momentum of the weights when the ship is inclined through a given angle, and the moment of the stability. Now by the formula for the stability

$$D \times GV = b\,I - D\,a\,s;$$

and since

$$W \times NQ = W \times NP \times \cos PNQ,$$

we shall have

$$W \times NQ \times \cos PNP = b\,I - D\,a\,s.$$

Hence

$$a = \frac{b\,I - W \times NP \times \cos PNQ}{D\,s},$$

furnishing in given terms the distance between the centre of gravity of the vessel and of its displacement.

(215.) In the practical case we have just adverted to, the transferred weights multipled into the distances they were respectively transferred, produced 264.5; and hence the preceding formula becomes

Application to the Scylla.

$$a = \frac{b\,I - 264.5 \cos 6° 20'}{D \sin 6° 20'};$$

or by further substituting for the elements b, I and D, we shall have

$$a = \frac{446.2 - 262.8}{50.85} = 3.6.$$

Now the centre of gravity of the displacement being 3.97 feet below the load water line, the distance of the centre of gravity of the whole ship below the same line will be $3.97 - 3.6 = 0.37$ feet.

(216.) At the time this experiment was performed, the Scylla had not her full complement of stores on board, her draught of water forward being 11 feet 6 inches, and abaft 14 feet 10½ inches. After her additional stores were taken on board, amounting to 33.4 tons, her draught of water forward was increased to 12 feet 6 inches, and abaft diminished to 14 feet 10 inches. The moment of these weights above the water line, estimated at the instant of sailing, was 193 tons, the height of the centre of gravity of the sails being taken as in a top-gallant breeze. The moment of the weights below this water line, at the time of the last experiment, was 401 tons; and hence

$$\frac{401 - 193}{494.4} = 0.42 \text{ feet},$$

giving 5 inches for the distance of the centre of gravity of the vessel below the water line at the time of sailing.

Mr. Barton's method.

(217.) Mr. Barton, Naval Architect, has proposed to run the whole or part of the guns aft, and to observe the new draught of water, together with the place of the guns moved. From these data and the draught of the ship he proposes to determine this centre.

Mr. Abethell's method.

Mr. Abethell, Assistant Master Shipwright at Sheerness, proposes to get rid of the difficulty of moving the weights, by attending to certain data when a ship is docked with the under side of the keel deviating from parallelism with the upper surface of the blocks, which is almost always the case. We may suppose, he says, by the falling of the tide in the dock, the after extremity of the keel to come first in contact with the blocks. Then as the tide continues to fall, the after body will be gradually forsaken by the water, and the fore part further immersed; a constant equilibrium being maintained between the total weight of the ship, and the pressure of the water against the immersed part of the body, until the moment the ship is aground fore and aft. At any intermediate instant, the ship may be considered as a lever of the second kind, of which the fulcrum is the transverse line or point of contact of the keel and after block, and the power and weight, the weight of the immersed volume and of the ship respectively, each acting in the vertical line passing through its centre of gravity. As we can by a ready calculation from the draught of the ship, discover its weight, that of the immersed volume, and the perpendicular distance of the line of pressure from the fulcrum, the distance of the vertical line passing through the centre of gravity of the ship is the only unknown quantity in the equation of moments to be determined.

(218.) Supposing A N, fig. 9, to represent the natural water line of the ship, and K L the water line just at the moment when the fore part of the keel touches the blocks; draw Q H through the centre of gravity of the volume K F M L perpendicular to K L, and F G parallel to Q H. Then supposing the whole displacement under its ordinary circumstances to be D, and that corresponding to K F M L to be d, and $GH = b$; if the line S E O be drawn parallel to Q H, at a distance G E from G equal to $\frac{b\,d}{D}$, it will as well as P B O pass through O, the centre of gravity of the ship.

Mr. Major's method.

(219.) Mr. Major has given an ingenious method for finding the centre of gravity of a ship. Let the vessel be heeled to the same constant angle, by two separate horizontal lines, applied at different heights in the plane of the masts. It will then be evident that the momenta of the forces resulting from the separate applications of the inclining forces must be equal, since the same constant force of stability represents them both. Let P and p represent these forces, and a, b the respective distances at which they act from the centre of gravity of displacement. Let Δ also be the angle of inclination of the ship from the perpendicular, and x the distance of the centre of gravity of the vessel from the centre of gravity of displacement. Then we shall obtain the following equation for the forces employed:

$$P(a - x)\cos\Delta = p(b - x)\cos\Delta,$$

and

$$x = \frac{P\,a - p\,b}{P - p},$$

determining in known terms the elevation of the centre of gravity of the whole vessel above the centre of gravity of the displacement.

Naval Architecture. Masts.

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On Masts.

(220.) Theory has done little towards informing us respecting the lengths and dimensions of masts; experience, the great nurse of the useful Arts, must here be our guide. The following Table is derived from Edye's *Naval Calculations*.

Dimensions of masts and yards.

Names of Masts, Yards, &c.		Dimensions.														
		120 Guns.			80 Guns.			74 Guns.			Razée 50 Guns.			52 Guns.		
		Length.		Diameter.	Length.		Diameter.	Length.		Diameter.	Length.		Diameter.	Length.		Diameter.
		Yds.	In.	In.	Yds.	In.	In.	Yds.	In.	In.	Yds.	In.	In.	Yds.	In.	In.
Lower masts.	Fore mast	36	28	36¾	36	0	36	32	30	31¼	32	30	33½	30	6	31
	Main mast	39	32	40	39	22	39¾	36	0	36	36	0	36	33	6	34½
	Mizen mast	27	8	24½	27	8	24¾	24	23	21⅝	26	16½	24	24	0	22½
Bowsprit		25	1	36⅞	23	35	36	22	0	34⅛	22	0	34⅛	21	18	31½
Fore	Top mast	20	34	20⅝	20	26	20¾	19	8	19¼	19	8	19¼	19	8	19¼
	Top-gallant mast	10	12	10¾	10	0	10	9	22	9⅝	9	22	9⅝	9	22	9⅝
	Lower yard	30	13	21¼	29	33	21½	28	4	19⅝	28	4	19⅝	28	4	19⅝
	Top-sail yard	21	18	13¾	21	20	13⅞	20	18	12¾	20	18	12¾	20	18	12¾
	Top-gallant yard	14	8	8⅝	12	34	8	13	12	8½	13	12	8½	13	12	8½
Main	Top mast	22	34	20⅝	23	0	20¾	21	22	19¼	21	22	19¼	21	22	19¼
	Top-gallant mast	11	17	11⅜	11	18	11⅜	11	0	11	11	0	11	11	0	11
	Lower yard	34	28	24⅜	34	15	24¾	32	8	22⅝	32	8	22⅝	32	28	22⅝
	Top-sail yard	24	20	15½	24	27	16	23	18	14⅝	23	18	14⅝	23	18	14⅝
	Top-gallant yard	16	9	10	15	12	9⅜	15	10	9¼	15	10	9¼	15	10	9¼
Mizen	Top mast	16	17	13¾	16	28	14	15	32	13	15	32	13	15	32	13
	Top-gallant mast	8	8	8⅝	8	8	8½	8	0	8	8	0	8	8	0	8
	Cross jack yard	24	20	15½	24	27	16	23	18	14⅝	23	18	14⅝	23	18	14⅝
	Top-sail yard	16	12	10⅛	16	12	10⅛	15	13	9⅝	15	13	9⅝	15	13	9⅝
	Top-gallant yard	12	3	6½	11	12	7	10	21	6⅛	10	21	6⅛	10	21	6⅛
Driver boom		23	7	13¾	23	13½	13⅞	22	27	12¾	22	27	12¾	22	7	12¾
Driver gaff		17	6	12⅝	17	13	12	16	35	11⅝	16	35	11⅝	16	35	11⅝
Jib boom		17	18	15¼	16	24	14½	16	0	14⅛	16	0	14⅛	16	0	14⅛
Sprit-sail yard		21	18	13¾	21	20	13⅞	20	18	12¾	20	18	12¾	20	18	12¾

Names of Masts, Yards, &c.		46 Guns.			Razée Corvette, 26 Guns.			28 Gun and 18 Gun Corvette.			18 Gun-brig.			10 Gun-brig.		
		Length.		Diameter.	Length.		Diameter.	Length.		Diameter.	Length.		Diameter.	Length.		Diameter.
		Yds.	In.	In.	Yds.	In.	In.	Yds.	In.	In.	Yds.	In.	In.	Yds.	In.	In.
Lower masts.	Fore mast	27	18	25	26	34	25⅝	21	18	19	19	33	20	15	18	16
	Main mast	30	0	28	29	12	28	23	24	20½	22	27	21⅜	18	6	17¾
	Mizen mast	21	25	19	20	25	19½	18	0	16¼						
Bowsprit		18	6	26½	18	4	26½	14	31	21⅛	14	16	20	12	0	17
Fore	Top mast	15	34	16⅛	15	10	16⅛	12	26	12¾	12	6	12¼	10	12	10
	Top-gallant mast	7	29	7¾	7	33	7⅞	6	13	6⅛	8	22	7⅛	6	18	6
	Lower yard	23	29	16⅜	23	19	16¼	18	12	12⅝	18	6	11⅛	16	0	11
	Top-sail yard	17	28	11½	17	20	11	13	24	8½	14	0	8½	12	18	8
	Top-gallant yard	10	35	6¾	10	24	6⅛	8	12	5½	9	6	6	8	24	6
Main	Top mast	18	0	16⅛	18	0	16⅛	14	14	12¾	12	35	12¼	10	12	10
	Top-gallant mast	9	0	9	9	0	9	7	7	7⅛	8	22	7⅛	6	18	6
	Lower yard	27	9	18⅞	26	34	18⅝	21	0	14½	18	7	11⅜	16	11	11
	Top-sail yard	19	24	12¼	19	24	12¼	15	18	9¾	14	0	8½	12	18	8
	Top-gallant yard	12	18	7¼	12	18	7½	9	16	6	9	6	6	8	24	6
Mizen	Top mast	13	24	11⅞	13	18	11¼	10	29	9	....		..	....		..
	Top-gallant mast	6	30	6⅞	6	27	6¾	5	16	5½	....		..	....		..
	Cross jack yard	19	24	12¼	19	24	6¾	15	18	9¾	....		..	....		..
	Top-sail yard	13	20	8¼	13	12	8	10	12	5⅞	....		..	....		..
	Top-gallant yard	9	12	5½	9	12	5¼	7	4	4½	....		..	....		..
Driver boom		18	21	11½	19	12	13⅛	14	23	8½	19	12	13½	16	32	11
Driver gaff		13	0	9⅜	13	22	9¾	10	30	7¾	11	12	9⅞	10	4	7½
Jib boom		13	5	11¾	13	1	11⅝	11	0	8⅞	9	0	8½	9	0	8
Sprit-sail yard		17	28	11½	17	20	11	13	24	8½	14	0	8½	12	18	8

Positions of ships' masts with regard to the length.

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74 guns	$\frac{5}{39}$ to $\frac{5}{43}$	$\frac{20}{35}$ to $\frac{20}{36}$	$\frac{20}{23}$ to $\frac{20}{24}$
Razée 50-gun ship..	$\frac{5}{43}$	$\frac{20}{36}$	$\frac{20}{24}$
52-gun frigate......	$\frac{5}{40}$	$\frac{20}{39}$	$\frac{20}{24}$
46-gun frigate	$\frac{5}{38}$	$\frac{20}{35}$	$\frac{20}{23}$
Razée Corvette of 26 guns	$\frac{5}{42}$	$\frac{20}{35}$	$\frac{20}{24}$
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Schooner.	$\frac{1}{5}$	$\frac{20}{31}$	
Cutter.	Mast $\frac{10}{25}$ of the length of the vessel on the load water line.		

Seppings' improved mast.

(222.) Sir Robert Seppings has invented a mast, at once distinguished for the beauty of the principle employed in its construction, and for its very great economy. According to this ingenious plan, the largest piece of timber required for a first-rate mast, is 40 feet long, and 10 inches square; whereas on the old plan, timber $22\frac{1}{2}$ inches diameter and 84 feet in length was required.

Its economy.

The mean expense stated by the officers of Deptford, Chatham, Portsmouth, and Plymouth Yards, for making a mast of a 74-gun ship, wholly of Riga timber, upon the old plan was £1246, and upon the new principle, of the same material, £306. In the instance of a 46-gun frigate, the cost upon the old plan is £631, and on the new £175. The whole saving in the main and fore-masts of 80 sail of the line would amount to nearly £100,000.

Exceeds old masts in durability.

(223.) It is also worthy of attentive consideration, that masts constructed upon the new principle, exceed in durability those of the old. The large timber required in the former plan, rendered it necessary to employ the yellow North American pine, in conjunction with the Baltic pine; a practice attended with the most disastrous consequences, since the mixing together of materials having different degrees of durability, limits the effective services of a mast to the least durable part of the materials of which it is composed. In the system of Seppings, *one sort* of wood only is employed, and therefore any decay arising from the improper admixture of materials is entirely removed.

Readiness with which it can be repaired.

(224.) The beautiful simplicity manifest in this mast renders also its repair or examination a matter of the greatest ease. In the event of any of the principal parts of a mast constructed on the old plan requiring to be replaced, full one-eighth of the mast was removed; but on the new system, independently of the facility with which the mast can be separated, not more than one-thirty-sixth part requires to be displaced.

Such masts can be inverted.

Another advantage resulting from the plan is, the being able to have either end uppermost. If a mast be wounded by shot or otherwise injured, and the damaged part can be housed below, the mast will frequently answer all the purposes required, by inverting it. Such an operation can be performed without removing any article essential to the construction of the mast. The facility, also, with which a mast may be fished or strengthened with iron instead of wood, deserves in the present instance an attentive consideration.

Mast can be sent abroad in separate pieces.

(225.) In the case of its being necessary to send a mast abroad, a vessel that can stow a piece of timber from 40 to 50 feet long, is equal to the conveying of a first-rate's mast in parts. The Blanche frigate of 46 guns, conveyed a fore mast for the Spartiate of 76 guns, in fragments, stowed upon her lower deck, which, on its arrival in South America, was with the greatest ease and convenience put together. In the old system, this service would require a ship equal to the receiving of a mast 140 feet long, and of proportionate dimensions; it being impracticable from the form and dimensions of the component parts, to be forwarded in pieces without the certainty of injury.

Description of a mast of a first-rate.

(226.) Fig. 1. plate ii. gives a side view of a first-rate's main mast, the second figure being a view on the foreside of the mast. Fig 3 is a section of the mast taken between A and B, fig. 1, and showing the equal and parallel arrangement of the parts composing the mast. The section denoted by fig. 4, exhibits the directions in which the treenails are driven, and fig. 5 denotes a similar thing respecting the ends. Fig. 6 shows the manner of disposing the treenails longitudinally. Fig. 7 is a section showing the method of fitting the bibbs. Fig. 8 is a sketch of the screw hoop. There being a tendency for the *outer* lips of the hoops to close before the inner, a piece of wood of a compressible nature must be placed between the lips at the outer part, in order to prevent it, as seen at W, fig. 8.

Mode of putting it together.

(227.) In putting the mast together, the butts are to be coaked with coaks 3 inches diameter and 6 inches long, as shown in fig. 2; and the four centre pieces forming the core or spindle of the mast, are to be treenailed together diagonally, as *e d*, figs. 4 and 6, by $1\frac{1}{2}$ inch treenails, placed 2 feet apart. Each pair of outer trees is to be fastened together, as shown at *i h* in fig. 4, with $1\frac{3}{8}$-inch treenails, driven about 2 feet apart. The whole of the mast is then to be connected together, as at *a b* and *c*, figs. 4 and 6, by through treenails $1\frac{1}{2}$ inch diameter, which are also to be placed at about 2 feet apart, care being taken that none of these treenails

come nearer to the outer butts than about 12 inches; and where they cross the treenails before driven, there must be a distance between them of about 6 inches. At the head and heel of the mast, fig 5, where the outer trees are tapered, ⅞ inch bolts are to be used instead of the treenails marked *i h*. The holes for the treenails are to be payed with mineral tar, as in those bored in the ship's side.

Necessary precautions.

(228.) Many precautions are necessary in putting the mast together. Great care is to be taken to bring the butts into close contact with each other; and moreover to place the outside butts in the same section, opposite each other, so as to be *exactly* under the middle of the hoops. The ekings, or arris pieces, are also to be butted under a hoop, and the butts are to be so spaced, as to give a good scarf to the outer butts of the mast. A chamfer is to be taken off the inner angle of the ekings, as shown in fig. 4; and the ekings themselves are to be screwed to the mast with screws, in addition to the hoops, if required. Nails are not to be used.

On the Sails of Ships, and on the Centre of Effort of the Wind on Sails.

Sails of ships.

(229.) The determination of exact and proper forms for sails is a problem of great importance in Naval Architecture. However admirable may be the properties of the hull, unless a proper regard be paid to the dimensions of the masts, and the disposition and quantity of the canvass with which they are covered, the vessel may be found not to possess any of the properties her projector fondly anticipated.

Effects of wind on the sails.

(230.) It is the impulse of the wind on the sails, which gives to a ship that headway which enables her to accomplish her destined voyage. This impulse evidently depends on the dimensions of the sails, so that a greater amount of canvass ought to produce an increased velocity in the ship. Hence sails are made as large as the other properties of the vessel will permit, but there are limits in every vessel, beyond which it would be dangerous to pass. In the following Table are recorded those dimensions of sails which the large experience of our seamen and Dock-yards seems to have sanctioned.

Dimensions of the principal sails.

The Dimensions of the Principal Sails.

Sails.	First Rate.			80.			70.			Rasée 50.		
	Head.	Foot.	Depth.	Head.	Foot.	Depth.	Head.	Foot.	Depth.	Head.	Foot.	Depth.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
Jib	....	52 6	81 6	....	51 0	78 0	....	50 0	78 0	....	50 0	82 0
Fore course	81 0	78 6	40 0	80 0	77 0	45 0	75 0	71 0	42 9	75 0	71 0	50 0
Top-sail	51 6	82 0	53 6	51 2	82 0	54 3	50 3	77 6	50 6	50 3	77 6	50 6
Top-gallant sail	38 6	54 9	28 8	34 8	54 9	27 0	35 9	51 3	26 4	35 9	51 3	26 4
Stay-sail	....	....	....	....	....	....	....	....	....	....	....	....
Main course	93 10	97 0	45 6	92 9	96 7	52 0	86 0	90 6	48 9	86 0	90 6	56 0
Top-sail	60 9	96 0	60 9	60 9	94 10	60 6	57 6	87 6	57 3	57 6	87 6	57 3
Top-gallant sail	43 8	63 6	32 6	40 1	63 6	32 6	40 3	59 0	30 0	40 3	59 0	30 0
Gaff top-sail	....	....	....	....	....	....	....	....	....	....	....	....
Mizen top-sail	41 9	63 6	43 6	41 9	63 6	44 0	38 6	57 6	41 0	38 6	57 6	41 0
Top-gallant sail	32 6	43 2	22 0	30 3	43 2	22 0	27 6	40 0	22 0	27 6	40 0	22 0
Driver	47 0	62 6	32 6 63 6	47 0	62 6	36 0 63 6	45 0	60 0	32 0 54 0	45 0	60 0	36 6 58 6
	52-Gun Frigate.			46.			Razee Corvette, 26 Guns.			28 Gun-ship.		
Jib	....	50 0	74 0	....	41 0	62 0	....	40 0	64 0	....	32 0	52 0
Fore course	75 0	71 0	41 0	64 0	62 0	39 0	63 0	62 0	35 6	49 0	47 6	31 0
Top-sail	50 3	77 6	50 6	42 6	65 6	42 6	42 0	65 0	41 0	32 6	50 0	33 6
Top-gallant sail	35 9	51 3	26 4	28 0	44 0	20 6	28 0	44 0	20 6	22 0	34 6	17 6
Stay-sail	....	....	....	....	....	....	....	....	....	....	....	....
Main course	86 0	90 6	45 0	73 0	76 10	41 0	72 6	76 0	42 3	55 8	60 0	34 0
Top-sail	57 6	87 6	57 3	46 6	74 6	47 0	46 6	74 0	45 6	36 6	56 9	36 0
Top-gallant sail	40 3	59 0	30 0	33 0	49 0	23 6	33 0	49 0	23 6	25 0	39 0	19 6
Gaff top-sail	....	....	....	....	....	....	....	....	....	....	....	....
Mizen top-sail	38 6	57 6	41 0	34 0	49 0	33 0	34 0	49 0	33 0	25 0	38 0	23 0
Top-gallant sail	27 6	40 0	22 0	25 6	36 0	18 0	25 0	36 0	18 0	18 6	27 0	14 6
Driver	45 0	60 0	32 0 54 0	36 0	51 0	31 0 51 0	35 0	53 0	28 0 49 0	30 0	39 0	25 0 41 6
	18 Gun Corvette.			18 Gun-brig.			10 Gun-brig.			Schooner.		
Jib	....	34 6	51 0	....	30 0	45 0	....	27 0	39 6	....	23 0	38 6
										Gaff	fore	sail.
Fore course	49 0	47 6	31 0	47 6	46 0	28 0	42 8	40 9	22 0	24 0	37 0	39 0 53 0
Top-sail	32 6	50 0	33 6	33 0	49 0	31 0	28 6	43 6	27 0	24 0	50 0	26 0
Top-gallant sail	22 0	34 6	17 6	23 6	36 0	24 0	23 0	30 6	18 0	20 0	30 0	10 0
Stay-sail	....	....	....	....	....	....	....	....	....	....	30 0	37 0
Main course	55 8	60 0	36 0	48 0	56 0	36 6	42 8	50 0	28 0	....	....	....
Top-sail	36 6	56 9	36 0	33 0	49 6	33 0	28 6	43 6	27 0	....	....	....
Top-gallant sail	25 0	39 0	19 6	23 6	36 0	24 0	23 0	30 6	18 0	....	....	....
Gaff top-sail	....	....	....	....	....	....	....	....	....	7 0	28 0	35 0 22 0
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Driver	29 6	39 0	27 9 45 0	30 0	49 0	32 0 50 0	28 0	47 0	23 0 41 0	25 6	50 0	43 6 59 6

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Naval Architecture.

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Naval Architecture.

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Sails.	First Rate.			80.			70.			Razée 50.		
	Head.	Foot.	Depth.	Head.	Foot.	Depth.	Head.	Foot.	Depth.	Head.	Foot.	Depth.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
Jib	....	52 6	81 6	....	51 0	78 0	....	50 0	78 0	....	50 0	82 0
Fore course	81 0	78 6	40 0	80 0	77 0	45 0	75 0	71 0	42 9	75 0	71 0	50 0
Top-sail	51 6	82 0	53 6	51 2	82 0	54 3	50 3	77 6	50 6	50 3	77 6	50 6
Top-gallant sail	38 6	54 9	28 8	34 8	54 9	27 0	35 9	51 3	26 4	35 9	51 3	26 4
Stay-sail	....	....	....	....	....	....	....	....	....	....	....	....
Main course	93 10	97 0	45 0	92 9	96 7	52 0	86 0	90 6	48 9	86 0	90 6	56 0
Top-sail	60 9	96 0	60 9	60 9	94 10	60 6	57 6	87 6	57 3	57 6	87 6	57 3
Top gallant sail	43 8	63 6	32 6	40 1	63 6	32 6	40 3	59 0	30 0	40 3	59 0	30 0
Gaff top-sail	....	....	....	....	....	....	....	....	....	....	....	....
Mizen top-sail	41 9	63 6	43 6	41 9	63 6	44 0	38 6	57 6	41 0	38 6	57 6	41 0
Top-gallant sail	32 6	43 2	22 0	30 3	43 2	22 0	27 6	40 0	22 0	27 6	40 0	22 0
Driver	47 0	62 6	32 6 63 6	47 0	62 6	36 0 63 6	45 0	60 0	32 0 54 0	45 0	60 0	36 6 58 6

Sails.	52-Gun Frigate.			46.			Razee Corvette, 26 Guns.			28 Gun-ship.		
Jib	....	50 0	74 0	....	41 0	62 0	....	40 0	64 0	....	32 0	52 0
Fore course	75 0	71 0	41 0	64 0	62 0	39 0	63 0	62 0	35 6	49 0	47 6	31 0
Top-sail	50 3	77 6	50 6	42 6	65 6	42 6	42 0	65 0	41 0	32 6	50 0	33 6
Top-gallant sail	35 9	51 3	26 4	28 0	44 0	20 6	28 0	44 0	20 6	22 0	34 6	17 6
Stay-sail	....	....	....	....	....	....	....	....	....	....	....	....
Main course	86 0	90 6	45 0	73 0	76 10	41 0	72 6	76 0	42 3	55 8	60 0	34 0
Top-sail	57 6	87 6	57 3	46 6	74 6	47 0	46 6	74 0	45 6	36 6	56 9	36 0
Top-gallant sail	40 3	59 0	30 0	33 0	49 0	23 6	33 0	49 0	23 6	25 0	39 0	19 6
Gaff top-sail	....	....	....	....	....	....	....	....	....	....	....	....
Mizen top-sail	38 6	57 6	41 0	34 0	49 0	33 0	34 0	49 0	33 0	25 0	38 0	23 0
Top-gallant sail	27 6	40 0	22 0	25 6	36 0	18 0	25 0	36 0	18 0	18 6	27 0	14 6
Driver	45 0	60 0	32 0 54 0	36 0	51 0	31 0 51 0	35 0	53 0	28 0 49 0	30 0	39 0	25 0 41 6

Sails.	18 Gun Corvette.			18 Gun-brig.			10 Gun-brig.			Schooner.		
Jib	....	34 6	51 0	....	30 0	45 0	....	27 0	39 6	....	23 0	38 6
										Gaff	fore	sail.
Fore course	49 0	47 6	31 0	47 6	46 0	28 0	42 8	40 9	22 0	24 0	37 0	39 0 53 0
Top-sail	32 6	50 0	33 6	33 0	49 0	31 0	28 6	43 6	27 0	24 0	50 0	26 0
Top-gallant sail	22 0	34 6	17 6	23 6	36 0	24 0	23 0	30 6	18 0	20 0	30 0	10 0
Stay-sail	....	....	....	....	....	....	....	....	....	....	30 0	37 0
Main course	55 8	60 0	36 0	48 0	56 0	36 6	42 8	50 0	28 0	....	....	....
Top-sail	36 6	56 9	36 0	33 0	49 6	33 0	28 6	43 6	27 0	....	....	....
Top-gallant sail	25 0	39 0	19 6	23 6	36 0	24 0	23 0	30 6	18 0	....	....	....
Gaff top-sail	....	....	....	....	....	....	....	....	....	7 0	28 0	35 0 22 0
Mizen top-sail	25 0	38 0	23 0	....	....	....	....	....	....	....	....	....
Top-gallant sail	18 6	27 0	14 6	....	....	....	....	....	....	....	....	....
Driver	29 6	39 0	27 9 45 0	30 0	49 0	32 0 50 0	28 0	47 0	23 0 41 0	25 6	50 0	43 6 59 6

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Centre of effort.

(231.) A knowledge of the exact position of the centre of effort of all the sails of a ship of each class, is an element of very great importance, and with the area of the sails, and some of the elements, are entered in the succeeding Table:

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Names of the Sails.	120 Guns.				80 Guns.				74 Guns.			
	Area of the Sails.	Centre of Effort.			Area of the sails.	Centre of Effort.			Area of the Sails.	Centre of Effort.		
		Above the Load line.	From the Centre of Flotation. Afore.	From the Centre of Flotation. Abaft.		Above the Load line.	From the Centre of Flotation. Afore.	From the Centre of Flotation. Abaft.		Above the Load line.	From the Centre of Flotation. Afore.	From the Centre of Flotation. Abaft.
	Feet.	Ft. In.	Ft. In.	Ft. In.	Feet.	Ft. In.	Ft. In.	Ft. In.	Feet.	Ft. In.	Ft. In.	Ft. In.
Jib	2132	73 0	135 0	....	1989	73 0	131 0	....	1950	67 0	118 0	....
Fore course	3210	52 0	76 6	....	3537	50 6	73 0	....	3120	45 9	67 2	....
Top-sail	3577	98 0	77 3	....	3600	98 0	73 0	....	3221	91 6	67 2	....
Top-gallant sail	1334	141 0	77 9	....	1205	141 0	73 0	....	1144	131 0	67 2	....
Main course	4305	53 6	....	11 0	4914	50 6	....	12 0	4300	47 6	....	12 0
Top-sail	4740	104 6	....	11 6	4704	105 6	....	13 0	4140	99 6	....	12 4
Top-gallant sail	1761	152 0	....	12 6	1682	153 0	....	14 0	1469	143 0	....	12 8
Mizen top-sail	2300	92 6	....	70 6	2314	92 6	....	65 6	1962	84 6	....	65 0
Top-gallant sail	836	126 6	....	71 6	806	126 6	....	67 0	737	116 4	....	65 9
Driver	2457	60 6	....	102 3	2825	53 0	....	95 0	2243	49 0	....	94 6
Total area of the sails	26652	....	....	....	27576	....	....	....	24286	....	....	....
		Ft.	In.			Ft.	In.			Ft.	In.	
The centre of effort of the sails, afore the centre of flotation		11	$9\frac{3}{8}$			9	$1\frac{5}{8}$			9	$7\frac{1}{4}$	
Ditto above the load water line		87	$1\frac{1}{2}$			83	$10\frac{1}{8}$			78	$5\frac{1}{2}$	
Load draught of water Forward.		24	7			21	9			20	11	
Load draught of water Aft		26	0			25	0			23	9	

Names of the Sails.	Razée of 50 Guns.				52 Gun Frigate.				46 Gun Frigate.			
Jib	2100	65 0	120 0	....	1850	58 0	117 0	....	1280	48 6	103 0	....
Fore course	3654	45 0	67 2	....	2993	39 9	65 0	....	2457	37 6	56 0	....
Top-sail	3221	93 0	67 2	....	3221	85 0	65 0	....	2241	76 4	56 0	....
Top-gallant sail	1144	132 6	67 2	....	1144	125 0	65 0	....	738	108 9	56 3	....
Main course	4928	47 0	....	12 0	3971	40 0	....	11 0	3075	37 6	....	10 0
Top-sail	4140	102 0	....	12 4	4140	90 0	....	11 6	2790	81 8	....	10 3
Top-gallant sail	1469	145 0	....	12 8	1469	133 6	....	12 0	972	118 3	....	10 6
Mizen top-sail	1962	83 0	....	65 0	1962	74 6	....	62 0	1369	68 9	....	55 0
Top-gallant sail	737	116 0	....	65 4	737	106 4	....	63 0	549	96 9	....	55 9
Driver	2421	44 0	....	92 0	2243	40 6	....	90 3	1783	38 0	....	67 6
Total area of the sails	25776	....	....	....	23730	....	....	....	17254	....	....	....
		Ft.	In.			Ft.	In.			Ft.	In.	
The centre of effort of the sails, afore the centre of flotation		10	$2\frac{3}{8}$			9	0			8	$1\frac{3}{4}$	
Ditto, above the load water line		76	$6\frac{7}{8}$			71	$0\frac{3}{8}$			62	6	
Load draught of water Forward.		20	3			19	5			17	6	
Load draught of water Aft		21	6			20	5			19	2	

Names of the Sails.	Razée Corvette, 26 Guns.				28 Gun ship.				18 Gun Corvette.			
Jib	1248	45 4	99 9	....	845	40 0	78 6	....	879	34 6	80 0	....
Fore course	2225	35 6	54 9	....	1500	29 0	43 0	....	1500	29 0	43 0	....
Top-sail	2193	72 6	54 6	....	1383	60 3	43 0	....	1383	60 3	43 0	....
Top-gallant sail	738	104 0	54 0	....	495	87 0	43 0	....	495	87 0	43 0	....
Main course	3142	35 0	....	10 0	1972	31 6	....	7 0	2082	30 6	....	6 6
Top-sail	2743	77 3	....	11 0	1674	65 3	....	7 3	1674	65 3	....	7 6
Top-gallant sail	972	113 0	....	12 0	624	96 0	....	7 6	624	96 0	....	8 6
Mizen top-sail	1369	65 0	....	54 0	724	56 0	....	41 0	724	56 0	....	41 6
Top-gallant sail	549	93 0	....	55 3	329	73 6	....	41 6	328	78 6	....	43 0
Driver	1694	35 0	....	76 0	1065	32 0	....	55 6	1242	26 6	....	59 0
Total area of the sails	16873	....	....	....	10611	....	....	....	10931	....	....	....
		Ft.	In.			Ft.	In.			Ft.	In.	
The centre of effort of the sails, afore the centre of flotation		5	$3\frac{1}{2}$			7	$4\frac{1}{4}$			6	1	
Ditto, above the load water line		59	$9\frac{1}{8}$			50	$5\frac{3}{8}$			48	$7\frac{3}{8}$	
Load draught of water Forward.		17	$0\frac{1}{2}$			15	2			14	8	
Load draught of water Aft		18	$5\frac{1}{2}$			15	7			15	3	

TABLE *continued.*

Names of the Sails.	18 Gun-brig.				10 Gun-brig.			
	Area of the Sails.	Centre of Effort.			Area of the Sails.	Centre of Effort.		
		Above the Load line.	From the Centre of Flotation.			Above the Load line.	From the Centre of Flotation.	
			Afore.	Abaft.			Afore.	Abaft.
	Feet.	Ft. In.	Ft. In.	Ft. In.	Feet.	Ft. In.	Ft. In.	Ft. In.
Jib	675	34 0	63 0	....	560	28 0	60 0	....
Fore course	1316	25 3	32 3	....	916	1 0	28 0	....
Top-sail	1272	55 6	32 3	....	962	42 6	28 0	....
Top-gallant sail	714	83 0	32 6	....	478	66 0	28 0	....
Main course	1716	28 6	....	16 0	1288	21 3	....	13 0
Top-sail	1355	63 3	....	17 0	962	48 9	....	14 3
Top-gallant sail	714	92 9	....	18 0	478	72 0	....	15 0
Mizen top-sail	....	....	....	....	....	....	....	....
Top-gallant sail	....	....	....	....	....	....	....	....
Driver	1619	30 0	....	39 6	1200	23 0	....	32 0
Total area of the sails	9381	....	....	....	6844	....	....	....
		Ft.	In.			Ft.	in.	
The centre of effort of the sails, afore the centre of flotation		2	4			3	$3\frac{3}{8}$	
Ditto, above the load water line		46	$3\frac{3}{4}$			35	$4\frac{1}{4}$	
Load draught of water: Forward		11	4			11	5	
Load draught of water: Aft		14	7			12	6	

Figure illustrating centres of gravity and centres of effort.

(232.) In fig. 9, plate ii., we shall find the centre of gravity of the several sails, together with the centre of effort of the whole system of sails, for two first-rates; the Britannia's class denoted by the strong lines A, and the St. Vincent's class by the ticked lines B. The plates given by Edye on this subject deserve an attentive consideration.

On the Resistance of Fluids.

Splendid names connected with resistance of fluids.

(233.) This subject, lying at the very root of Naval Architecture, is very defective, notwithstanding the efforts made by the most transcendent minds for its improvement. We may mention the names of Newton, Huygens, Euler, Daniel Bernoulli, D'Alembert, Don Juan, Bouguer, Condorcet, Borda, Bossut, Chapman, and many others, to show that no ordinary interest must attach itself to a subject, which, independent of its many useful applications, has offered so many attractions of high scientific interest.

Properties of a ship divided into two heads.

(234.) In a general way it may be said, that the properties of a ship may be classed under two general heads with regard to the fluid on which it floats; *viz.* those independent of any change of situation, and those which are called into activity when the body is in motion. In the midst of the difficulties which attach themselves on all sides both to the theory and experimental elucidation of the subject, it is fortunate that the great elements on which the safety as well as the general efficiency of a ship depend, are to be found among the former, and may be estimated with certainty and correctness; while those which relate to the form most essential to velocity, and which though not essential, are nevertheless of the greatest relative importance, are invested with the greatest difficulties, and to be found among the latter. Should the progress of knowledge at any future time disclose to us the real functional equations on which this important subject depends, Naval Architecture will make a greater and more decided step than it has ever yet done.

General circumstances on which the resistance to ships depends.

(235.) Our limits will not permit us to pursue this subject into its varied and beautiful details, and we must, therefore, content ourselves with recording generally, in the words of Dr. Inman, the circumstances on which the resistance to ships moving with the same velocity seem to depend:

First, on the area of the midship section, as causing a greater or less displacement of fluid by the motion of the ship.

Secondly, on the form of the fore body, as causing more or less additional resistance from the motion of the ship, considering only the inertia of the particles displaced; that is, supposing the void space left astern in consequence of this displacement to be instantly filled again by the fluid.

Thirdly, on the form of the after body, as causing a greater or less diminution of pressure forward, on account of the motion of the ship alone.

Fourthly, on the shape of the whole body, as affording a more or less easy and rapid transit of the displaced fluid to the stern, or to the void space, which would otherwise be left behind the ship for an instant.

Fifthly, on the form of the whole body, with respect to direction and the quantity of superficies, as causing more or less friction, and more or less adhesion of the fluid.

On the Stowage of Ships.

Stowage, its importance.

(236.) The best constructed ship may be so badly stowed, that she may fail to gratify in any way the ardent expectations of her constructor.* On the other hand, an experienced seaman, intimately conversant with

* The Thunderer 84, recently commissioned, affords an example. Built after the best model, as is understood, yet when commissioned by that thorough-bred sailor Captain Wise, and stowed exactly accordant to the plans and directions furnished to him, she was found entirely to fail. After leaving Sheerness, she took in 90 tons of additional ballast; and on her arrival at Malta, she was entirely restowed.

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the mechanical effects of stowage, may correct many of the errors of a badly formed vessel. Hence an attentive consideration of the effects of stowage is of the greatest importance to Naval Architecture.

Stowage applied to movable weights.

(237.) By the stowage of a ship is meant the disposition of her ballast and stores. Many of the weights in a ship, are necessarily fixed by circumstances, and it is, therefore, only to the movable weights, the ballast, and part of the stores, that any inquiries respecting the effects of stowage can be applied.

Stores and ballast.

(238.) The quantity of stores and ballast in a ship is one of the very first elements in the great problem of stowage.* This must depend on the class of vessels, and the service for which they are intended. As a general principle it may be remarked, that no ship should be incapable of stowing four months' provisions, with the necessary complement of stores. There can be no doubt that some improvements might be made in the forms of ships, so as to diminish considerably the amount of ballast. The degree in which this can be done, must be ascertained by experiment.

Many elements of a ship connected with stowage.

(239.) There are many elements of a ship intimately connected with the stowage. Among these may be mentioned the stability, rolling, pitching, scending, preserving a steady course, ardency, or tendency to fly up to the wind, going about, action of the rudder, and the strain of the materials.

In what way it influences the stability,

(240.) On the stability, the stowage exercises an influence, on account of the ballast and the movable weights governing in a great measure the position of the centre of gravity, which is an element intimately connected with it. When the stability requires to be augmented, it is necessary that the ballast should be distributed as low as possible; and the nearer it can be brought to the middle parts of the ship, the lower it will be. The form of the bottom of the vessel must exercise an important influence here, and shows how intimately the stowage is connected with the principles of construction.

the rolling,

(241.) The influence of stowage is, also, very considerable on the action of rolling. The skill of a Naval officer is displayed, when by changing the movable weights he is enabled to correct in any way the motion of rolling, and a similar remark may be made respecting the pitching and scending. We

pitching, and scending-

are, at present, much in the dark respecting the influence of stowage on these important elements; and very much that is done seems dependent more on accident than on rule. The sailor has abundant

The sailor can do much towards improving the stowage.

opportunity in these particulars to assist the Naval Architect; nor should the latter neglect the consideration of those apparently trivial causes to which the sailor often attributes the successful sailing of his vessel. The further the weights are removed from the centre of gravity, the greater is the resistance to quick and uneasy rolling; and to reduce the depth of the pitching and scending, as many of the movable weights as possible should be brought near the middle of the vessel. The practice of "winging the weights," as it is technically termed, is found to be fully justified by experience.

* It is an important problem, and has occupied the attention of the greatest Geometricians. The Academy of Sciences on many occasions directed the attention of Geometers to it. Among the great names connected with its history may be mentioned Daniel Bernoulli, Euler, the Abbé Bossut, J. A. Euler, and Bourdé de Villehaut.

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Yawing.

(242.) There is, sometimes, a disposition in a ship to turn from its direct course, increasing thereby the difficulty of steering, and more or less retarding the advancement of the ship. This among sailors is termed yawing. To correct any error of this kind, the movable weights should be so placed that their centre of gravity may be before the middle of the ship's length. The moment of the lateral resistance abaft the centre of gravity, will by this means be increased, and the moment forward diminished.

Mean direction of the water.

(243.) When a ship is completely stored and in perfect trim, the mean direction of the water passes a little before its centre of gravity; but since during the progress of the voyage there must have been a loss of consumable stores, the trim she originally possessed may be very much changed. The weatherly qualities, which made her the admiration of the seaman on leaving port, may either be lost altogether, or in a very great degree impaired. Hence the necessity of stowing the movable weights, so that the consumable stores being taken in proper proportions from the fore and after parts of the ship, the good qualities she originally possessed may be retained as her draught of water becomes successively decreased.

Consumable stores

Tacking.

(244.) In the case of tacking, the resistance a ship experiences in coming about depends on the lateral resistance of the parts before and abaft the centre of gravity. This resistance will be a minimum when the centre of gravity is in the middle of the length.

Resistance of rudder.

(245.) The power of the rudder to turn a ship being proportional to the distance of the centre of its mean resistance from the centre of gravity, the movable weights must be so placed that the centre of gravity of the ship may be before the middle of its length.

Weights of transverse sections and upward pressure corresponding.

(246.) With respect to the influence of the stowage on the materials composing the framework of the ship, too much attention cannot be paid to the relation between the weights existing in the several transverse sections of the ship, and the upward pressure of the water at the corresponding parts. The figure of the ship, and the unequal distribution of the weights, occasions at all times a longitudinal strain, producing arching, or as it is sometimes called hogging. To equalize, as much as possible, these actions, should be another great object of the Naval Architect; and although the necessary existence of great weights at the extremities, may prevent a perfect equilibrium with the buoyancy of the corresponding parts, as far as circumstances permit, attention should be paid to the placing of the weights where the buoyancy of the body is best able to sustain them. This requires the ballast and heaviest weights to be placed in the full parts of the body towards the midship section; reserving, however, the immediate vicinity of the main mast free from the heaviest weights.

Relation of the stowage to the qualities influenced by it.

(247.) Amidst these diversities, and apparently opposing qualities, it is, however, remarkable, as Mr. Morgan observes, that the modes of stowage required, by a due attention to the qualities influenced by it, are generally compatible with one another. The stability requires the greatest weights as low as possible, which accords with their concentration towards the middle of the length, a condition required to produce the best effect on the pitching, tacking, and strain of the materials. Holding a steady course, and the action of the rudder requires the weights to be placed so that the centre of gravity of the ship may be before the middle, but not so much as to be *practically* opposed to the

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consideration of its being very near to the middle, which reduces the resistance to coming about. The rolling requires the weights to be winged, which a skilful sailor knows how to manage without unduly raising the centre of gravity—an effect which would impair the stability. The result of all these conclusions is, that the movable weights in a ship should be so disposed, that its centre of gravity may be low and a little before the middle of its length; and that they should be winged as much as possible without raising the centre of gravity.

Experiments wanting.

(248.) A course of experiments on the quantity of ballast and the best disposition of weights, adapted to every class of ships, would be productive of great advantage to Naval Architecture. By determining, continues Mr. Morgan, the proper trim of the different classes of ships, much valuable information would be obtained for making designs. At the present time calculations depending on a supposed set of a ship in water have frequently to be altered. The time doubtless will come when this subject will be better understood.*

Rolling, Pitching, and Scending.

Rolling, pitching, and scending.

(249.) The action of the wind and the troubled surface of the sea destroy all those relations of equilibrium we have been hitherto contemplating, and new mechanical conditions, involving some difficult branches of analytical inquiry, are hence called into activity. The peculiar movements which these varied and uncertain forces occasion in a great volume like a ship, in so many different ways, have rendered an attention to this very important subject indispensably necessary. Not only do the rolling and pitching of a vessel, and those elevations and depressions which her whole body undergoes, intimately concern all who may be engaged in her navigation, and influence very materially all her sailing qualities, but the strength of the fabric of the ship itself, and the expense of her wear and tear depend greatly upon them.

Important consequences connected with them.

Easy movements of some ships.

(250.) Experience tells us, that among the innumerable ships which the enterprise of modern times has constructed, there are some which perform all their movements with ease and comfort to those who command them, and whose accidents and casualties, amidst all the uncertainty attending a seafaring life, amount to much less than many others of the same class. Of the Caledonia for example, it was said by her officers in their official communications, "*that she rolled in the trough of the sea quite easy*;" whereas, in the case of the Anson of 38 guns, which had originally been a 64, in her very first voyage the rolling was so excessive, that she sprang several sets of topmasts; and although endeavours were made to correct it by alterations in her masts and yards, she continued still to be a very uneasy ship, with an excessive wear and tear.*

Contrary properties of others.

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Examples of different ships

(251.) That there are innumerable intermediate stages of diversity between these two perhaps extreme cases may be gathered from many sources. Of forty 74-gun ships built nearly at one time from the same draught, and constituting a class by themselves, it was reputed that the Cressy, Blenheim, Armada, Poictiers, Conquestadore, Glocester, Rippon, and Clarence, rolled *tolerably easy* in the trough of the sea. The Leonidas and Shannon, 46-gun frigates built after the draught of the French Hebe, were said to roll *deep without jirking*; and of the 18-gun brigs, their rolling in the trough of the sea was stated to be *easy*. Of the 10-gun brigs, also, their rolling was said to be *middling easy*.

(252.) To inquire in some degree into the general question of rolling, is therefore one of vast interest to ship-building, and we regret that our exceedingly narrow limits can do little more than glance at its more prominent heads. Rolling may arise either from the impulse of a wave on the side of a ship, acting in some direction above her centre of gravity, or from the undulations of the waves themselves. Suppose, by way of example, A D B, fig. 1, pl. iii., to be a section of a ship, A B its load water line, E the centre of gravity of the whole ship, and G its metacentre. Suppose, also, B H to represent the direction of the impulse necessary to give it the inclination *a b*. The moment of the effort producing this inclination, will hence be in proportion to E H, and the moment of the effort tending to restore the vessel to its upright position, will be as the line E G. These efforts, acting in contrary directions, occasion rolling; the effect of the force producing it being as the sum of E H and E G. With regard to the undulations of the waves, a ship's rolling must commence the moment a wave rises on one side and sinks on the other. The inclination of the side of a wave is continually changing by imperceptible degrees,

What occasions rolling.

Example.

When rolling commences.

* The practical stowage of a ship depends principally on the master. When a ship is newly commissioned, this officer is directed by the Admiralty Instructions to obtain the most correct information he can of the manner in which the hold was stowed when she was last in commission, and what then were her qualities, that the stowage may be altered, with the sanction of the captain, if there be reason to suppose it may be done with advantage. If the ship have not been at sea, the master is then to consult the master shipwright of the Dock-yard. When the stowage of the hold is completed, the master is to enter in the log-book a particular account of the manner in which it is stowed, specifying the quantity of ballast in each hold, and the manner in which it is arranged.

* This ship was cut down in 1794; and Mr. Wilson of the Navy Office, a competent authority, remarks, "that although in all other Maritime States, the Science of Naval construction was well understood, yet so culpably ignorant were the English constructors, that this operation, so well calculated, when properly conducted, to produce a good ship, was a complete failure. Seven feet of the upper part of the top sides, together with a deck and guns, making about 160 tons, were removed, by which her stability was greatly increased; but by a complete absurdity, the sails were reduced one-sixth in area. Her masts and yards were afterwards increased to their original size, but as there was no decrease of ballast, she was very little improved."

Other sixty-fours were cut down, masted and ballasted in the same manner, and with similar results; and although they were improved by enlarging their masts and yards, they were still bad ships. A failure in this instance was indeed a national misfortune; for had Science been applied to their cutting down, a class of frigates might have been formed, capable in every way of coping with the large American frigates. The disasters of the late war might thus not merely have been avoided, but have been converted into events of quite an opposite character. Let those who decry Science, and check in every way its application to Naval Architecture, read in the pages of the last American war their utter condemnation. A very little Science would have enabled our Naval Architects at that time to have changed a ship of excessive stability, which must always be an uneasy one, into one of easy rolling. Instead of having reduced the masts and yards to those of a 38-gun ship, had they been a little increased, and at the same time half her ballast taken out, and her guns, moreover, changed for others of a larger caliber, instead of some of them being smaller, such a ship would have been easy, would have sailed better than any class of ships then in the Navy, and the expense of its wear and tear would not have exceeded the ordinary amount.

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Heeling of a ship round a longitudinal axis. Axis of rotation.

from a horizontal position to its greatest angle of inclination, and *vice versâ;* and therefore the force whose tendency is to turn the ship increases only by slow degrees; and long before she has arrived at that angle of rolling, which even a small inclination of the side of a wave would give, an opposing wave mounts on the other side of the ship, and prevents her further depression.

It sometimes rises,

(253.) There are many circumstances connected with the heeling of a ship round a longitudinal axis passing through its centre of gravity which it may be necessary very briefly to advert to. The axis of rotation (considered quiescent) round which the motion of rolling is performed, is far from maintaining at all times a constant elevation. In some cases it rises and in others falls, and sometimes, it is true, it remains the same. It has been found, for example, that when there is a tendency to immerse a greater solid below the water on one side than is raised above it on the other, the axis of rotation must rise during the inclination; and the reason is evident, since displacement on any other supposition would be increased, and a greater buoyancy exist than before, and consequently a greater buoyancy than the weight of the ship would balance. In such a case, whenever the motion of rolling is performed, the vessel must rise in heeling, and fall in righting again. On the other hand, if a rotation round the same axis (under similar quiescent conditions) immersed a less volume below the water than it raised above it, the same alternate rising and falling would take place, but in a contrary order; that is, the vessel would fall in heeling and rise in righting again.

and sometimes falls.

The same thing but in a converse order.

The amount of rolling depends on the centre of gravity of the ship.

Examples.

(254.) The existence and amount of this motion, which, according to the degree in which it prevails, must render the rolling of the vessel violent and uneasy, depend on the position of the centre of gravity of the ship, and on the form of the sides between wind and water. If we take the case of three vessels, each of which has its sides parallel to the plane of the masts as in fig. 2, 3, 4, plate iii., A B being the load water line in their upright positions, and $a\,b$ that when the vessel is heeled at an angle of 10°, G, the centre of gravity of the vessel, being supposed equally distant from the two water lines, coincident, moreover, with the surface of the water in the first position, below it in the second, and above it in the third. Then since in fig. 2 the immersion and emersion are equal, the vessel as it heels can neither rise nor fall; and as in fig. 3 the immersion is greater than the emersion, the vessel must rise in heeling; so in fig. 4 the immersion being less than the emersion, the ship will fall while performing the same motion.

(255.) If, however, the sides of these vessels are made to fall out above the load water line, some changes will be found to take place. In the case of fig. 2 the immersion will in this case exceed the emersion, and the axis of rotation, supposing it to remain quiescent, will rise. In the case of fig. 3 the immersion will exceed the emersion more than before, and a still greater rising in the ship take place than before; and in fig. 4 an increase of the immersion will also take place, and hence a decrease in the falling of the vessel. If, on the other hand, the sides of these vessels fall out below the water line, and preserve their parallelism above it, the ship denoted by fig. 2 will fall in heeling, the rising of fig. 3 would be corrected, and the falling of that denoted by fig. 4 increased. Wherever, therefore, there is a great disproportion between the immersion and the emersion, the axis of rotation being supposed quiescent, in large angles of rolling, the shocks resulting from the ship's rising and falling must be very great. To avoid such an important error in construction, it is necessary to find by computation the exact position of the ship's centre of gravity, and then to alter the body till the immersion and emersion caused by heeling round a quiescent longitudinal axis passing through that point are equal. A like attention must be paid to the pitching of a vessel; for any great inequality between the immersion and emersion round a quiescent axis would be attended with similar bad effects. The motions of rolling and pitching are hence most uniform and most free from sudden shocks, when the centre of gravity of the ship is in or near the plane of the load water line. Should circumstances not permit the centre of gravity to be brought into the plane of the load water line, it is proper to endeavour to bring it as near to it as possible. It may be further observed, that as the keel and the lower parts forward and aft contribute in a very great degree to diminish the rolling by the direct opposition of their surface to the water, the further these parts are removed from the axis of rotation, the greater will be the effect they produce in diminishing the rolling; and for this reason also, when the centre of gravity is in the plane of the load water line, the ship should roll less. The form of the ship, moreover, near the load water line will influence its motion also.

How shocks may be avoided.

When rolling and pitching are most uniform.

These motions illustrated by a pendulum.

(256.) These peculiar motions of a ship have been sometimes illustrated by the movement of a pendulum oscillating in the same time as a ship. If for example P, p, &c., denote the particles of a ship, and D, d, &c. their distances from the axis of rotation passing through the centre of gravity, the length of such isochronal pendulum will be

$$\frac{P D^2 + p d^2 + \&c.}{\text{whole ship} \times E G},$$

where E is the centre of gravity, in this case the centre of suspension, and G is the metacentre, on which the whole buoyancy of the fluid equivalent to the weight of the ship acts upwards. Supposing the functions $P D^2$, $p d^2$, &c. to be given as well as the weight of the ship, the length of the isochronal pendulum will vary inversely as E G; or in other words, that the greater is the elevation of the metacentre above the centre of gravity of the ship, the shorter will be the pendulum, and the quicker the vibrations of the ship; and on the other hand, the less that distance is, the slower will the rolling become. Supposing the line E G and the weight of the ship to be given, the duration of the vibrations will vary with the values of D, d, &c.; and the less those values are, the shorter will be the pendulum and the quicker the rolling; and on the contrary, the greater are the vibrations, the slower it will be. It must, however, be remarked, that the conclusions thus arrived at are absolutely true only when the vibrations are evanescent; but that they may be regarded as nearly true when they are in a practical sense very small. When a ship rolls through finite angles, the vibrations are very different from those of a pendulum of an invariable length, the point G not being then a fixed point.

Difficulty of constructing a ship that shall have proper stability and roll easily.

(257.) It is no easy matter to construct a ship which shall possess a proper stability and also, at the same time, perform her motion of rolling easily, although this is a point at which the Naval Architect should continually

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aim. It has been observed, that an undue attention to one of these properties has been obtained at the expense of the other. If the stability be diminished, the heeling of the vessel will be increased by the same amount of acting force; but the heeling as well as the righting of the vessel will be more slow and easy. The stability cannot, however, be diminished too much without endangering in a great degree the safety of the ship. On the other hand, while an increase of stability diminishes the heeling of the ship,—and which confined within proper limits produces wholesome effects; yet when carried to excess, the inclining force is so suddenly destroyed, as to produce shocks of the most dangerous kind. A wave acting on the side would produce a powerful effect, so that a ship thus constructed, would in the least sea be subject to continual and quick vibrations. It has been remarked by some writers, that the height of the metacentre alone determines the properties of a ship with regard to the qualities of its rolling; but it is possible that the height of this point may be something diminished, and yet the forms of the sides be so determined as to impart a stability sufficiently great. The height of the metacentre may, however, be increased beyond its usual limits, and, nevertheless, by injudicious alterations in the forms of the sides, the stability be found too small.

Summary calculations.

(258.) Inman recommends, in order to form a proper estimate of a ship's properties in this respect, to make accurate calculations of the stability at different angles of inclination, and to compare the result in each case with the stability of approved ships of the same class. Hence, also, he adds, that to enable the Naval Architect to design ships which may be expected to possess the requisite stability, he must be furnished not only with all the necessary calculations for the different kinds of ships already built, but also with a minute detail of their performances at sea. Thus we see how intimately blended are the pursuits of the Naval Architect and the sailor.

Greatest difficulty with merchant ships.

(259.) It is a much greater difficulty to determine the necessary relations between the stability and the rolling in merchant ships, than in those intended for the purposes of war. In the former class of vessels, the object is to obtain the greatest possible burthen, at the least possible expense of the ship. Hence vessels of this kind should be very full below, and have but very little height above the water in proportion to their breadth. The centre of gravity of the displacement will thus be very low, and consequently the metacentre also. Hence, also, the centre of gravity of the cargo must be brought as low as possible, to ensure the requisite stability. The result of all this is the quick rolling of the ship and violent shocks, which, however, may in some degree be diminished by winging the weights as much as circumstances will allow.

Remarks on centre of gravity.

(260.) Economy in the navigation of merchantmen requiring as small a number of men as possible, a less quantity of sail is rendered necessary, and hence a less distance between the centre of gravity of the vessel and its metacentre, a circumstance which, as we have before seen, makes the motion of rolling much easier.

(261.) Ships of war which have not occasion for so great an amount of capacity below, and require velocity, may be so constructed as to have their centres of gravity higher. The metacentre ought, therefore, to have such a height above the water, that the common centre of gravity of the ship and of the weights may be brought nearly to the plane of the load water line, and that the ship may still be sufficiently stiff in resisting heeling.

(262.) There is, however, another species of rolling which takes place with regard to the length, to which we must not omit to advert. In this case the extremities of the vessel rise and fall. The fore part of the ship being raised by a wave, it falls again when that wave has passed; and any motion thus imparted to a ship would very soon cease, did not another wave follow to raise the bow of the ship again. When a ship is close to the wind and meets the waves, it often happens after a sea has passed the fore part, that it suddenly falls and raises itself with difficulty upon the following wave, and in such a case the ship is said to *pitch*. When a wave has passed the fore part of the ship, and is arrived near the middle, a space of considerable dimensions is left void near the bows, and the ship there is left quite unsupported. The vessel, therefore, precipitates itself with a very great momentum, indicated by the product of all the weights in the fore part of the vessel, multiplied by their distance from the point at which the ship is unsupported. Sometimes the after part falls heavily, and the ship is said to *scend*. This results from a similar cause and has the same inconveniences. Both these motions very much impede the motion of the ship, the whole fabric of the masting undergoing the greatest shocks and strains. Every part of the body of the ship suffers also greatly, there being a constant tendency in all its parts to separate. This must occasion prodigious strains on all the fastenings, and calls for the greatest attention on the part of the Naval Architect.

Pitching.

Scending.

Fastenings.

(263.) This kind of motion, and all the resulting strains must hence be different in different kinds of ships. The same amount of fastening, therefore, which may be quite sufficient for one kind of ship may be altogether insufficient for another. In vessels which are very full near the load water line fore and aft, and very lean below, the pitching and scending are very great. Such a state may, however, in some degree be relieved by an attention to the distribution of the weights. The errors of the Naval Architect may be more or less corrected by the experienced seaman. It is manifest that when the weights in the fore part of the ship are carried near the middle, the effect of the ship's plunging in this part will be less; and not only must this motion become less quick, but succeeding waves will have less difficulty in raising it again; and a similar remark applies to the after part. Hence much relief may be afforded to these motions of a vessel by bringing the weights as much as possible in the neighbourhood of the middle of the ship. There are some weights which it is impossible to move, and which produce a great effect, such as the fore mast and its rigging, the bowsprit and its anchors. The mechanical effects of these the ship-builder must be prepared to resist by the figure and strength of his fabric.

Concentrating the weights.

Other motions.

(264.) There are motions, however, of another kind, intermediate between rolling and pitching, or rolling and scending, and which exercise an important influence on the movements of a ship. When a vessel floats quiescently on the surface of the sea, the centres of gravity of the displacement and of the whole ship are in the same vertical plane; but when the vessel is inclined, the latter point is carried to leeward, and the buoyancy of the water, acting upwards through it, endeavours to turn the ship back. The axis round which

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the ship revolves in such a case, must hence depend on the position of the centre of gravity of displacement. If this latter centre be in the transverse section passing through the centre of gravity of the ship, the vessel will revolve about an axis parallel to the length; but if it be either before or behind it, the buoyancy will cause the ship to revolve round an axis, occupying a place between the transverse and longitudinal axes of the vessel. Each different inclination may hence be accompanied by an axis peculiar to itself; and hence a system of movements may be produced tending to disunite all the parts of the ship, deranging its different adjustments, and operating greatly in retarding its progress.

How to counteract them.

(265.) To counteract motions so injurious as these, the centre of gravity of the displacement, both when the vessel floats upright, and when it is inclined at different angles of inclination, should at all times be found in the same vertical plane. This must be done by assigning to the volumes immersed or emerged in consequence of the inclination, such particular forms, that the line joining their centres of gravity shall in all cases be parallel to the transverse section. This important consideration, it appears, was first attended to in English ships by Dr. Inman. By comparing the reports made on different ships in his Majesty's Navy, with calculations made on their drawings, it appears that these vessels have the best character for regular and easy motion, *cæteris paribus*, that have this property.

On the Arching of Ships.

Arching of ships.

(266.) Our ordinary experience proves how difficult it is, in the simplest combinations of carpentry, to preserve precisely the figure that may have been intended; and the ingenuity of the workman is frequently taxed in devising braces and ties in order to maintain it. In a far greater degree is the Naval Architect called upon to devise means for preserving to a ship, when she is launched, the same figure she possessed when resting on her shores. To accomplish this demand a large share of practical knowledge combined with an acquaintance with the theoretical wants of Naval Architecture. The ingenious constructor cannot but be anxious that his ship should retain, when she sails in all the pomp and busy circumstance of war, and when innumerable strains are acting upon her, the properties he originally desired her to possess.

(267.) We can hardly imagine a more mortifying circumstance than to find, after every imaginable care has been bestowed upon a design, that the moment the vessel is launched, some of her essential conditions are altered, her hull exhibiting unequivocal signs of weakness, her extremities dropping, and her whole frame becoming arched. It is the business of theory not only to plan the ship, but to devise means for constructing her so that her exact theoretical form shall be preserved.

Combining of timbers a difficult subject.

There is more science in combining timbers together than is commonly imagined; and when we see how difficult it is, even in the simple fabric of a gate, a partition, or a roof, to preserve entirely the form that was intended, we cannot but observe in the larger and more complicated fabric of a ship how greatly the difficulty must be augmented. Here it is that theory and practice can do so much to aid each other. In all the mechanical arts they should be inseparably bound together, and yet how seldom are they thus allied! A narrow jealousy and mistrust too often divides them.

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Why peculiarly so in the case of a ship.

(268.) There are circumstances, moreover, of a very peculiar nature, which in the case of a ship contribute to produce this derangement of form, and which it is fitting the Naval Architect should be made intimately acquainted with. It is not only in a storm that her fastenings are disturbed, and her timbers exposed to different strains from those which they underwent when she was supported in the dock, but even when she floats in tranquillity in the harbour, destitute even of her masts, and her most ordinary stores. The simple hull itself is compelled to bend by the buoyancy of the very fluid on which it floats.

Cause of weakness.

If a straight line be drawn from the head to the stern, whilst the vessel is on the slip or in dock, no sooner has she entered her own element, than each end of this line will be found to have dropped from two to six inches, in consequence of the weakness of the fabric. In cases of arching, also, some of the butts of the planks are always found to have parted aloft, at the same time that the angular position of some parts of the structure has as uniformly been more or less altered; and very generally a certain degree of sliding is observable in the planks at the sides of some of the ports. This sliding was seen very distinctly by Dr. Young in the planks of the Albion and of the Belliqueux, at the same time there were also obvious indications of a certain degree of extension and compression. In the Albion the butts of the planks were parted so far, that in some instances pieces were let in between them; and in the Belliqueux there was a space of about five inches between the middle of the deck transom and the carling, which had originally been in contact with it. In the Asia, the arching amounted to three inches and a quarter, and the comparative length of the upper and lower parts was probably altered about two inches at most: the parting of the butts amounting to three-sixteenths of an inch each, "for upwards of fifty feet in length in the midships, and for about eight feet from the top side," making a total extension of probably less than an inch; so that about half the effect seems to have been produced in one way, and half in the other; but apparently the greater half by the want of stiffness. Some degree of permanent compression or crippling below has been observed, the butts of the planks opening when the cause of arching has been removed, and the sheathing being more wrinkled than would have happened from the simple bending of the planks.

To correct this was the problem undertaken by Sir Robert Seppings.

To correct these serious defects was one of the great problems undertaken by Sir Robert Seppings. Before his time, all the materials composing the fabric of a ship were disposed nearly at right angles to each other; a disposition not sanctioned by any authority, nor by the humblest maxim of mechanical knowledge. A ship too from its great length, and the peculiarity of its form, is the body calculated to display erroneous combinations in the most remarkable degree.

(269.) The length of a 74-gun ship being 170 feet or more, it requires but little knowledge of materials to perceive that planking of such a length, whatever be its amount of thickness, or the mode or way in which it is joined together, must under such a system bend with its own weight. The fastenings and connections of the several parts of such a fabric, cannot therefore but suffer from a want of stiffness, and a change of form must be the consequence.

(270.) The truth of the principle here adverted to is confirmed by every day's experience. The idle schoolboy racks the frame of his slate, loosening its fastenings,

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and deranging its figure; and the country carpenter finds, however he multiplies his *parallel* rails or bars, and whatever ingenuity he displays in their fastenings, the uniformity of his gate will soon be destroyed, unless he adds a brace or diagonal timber to his fabric. In a popular sense we may say the old system of timbering resembled in principle fig. 5, plate iii. and the new system fig. 6. It is obvious, to adopt the familiar language of Seppings, the greater the length of the frames, the greater will the superiority of the latter be shown.

Effects of a triangular combination of timber.

(271.) The effect of a triangular combination of timbers like this is, that the pieces disposed horizontally are acted upon as ropes by a strain of the fibre, whilst the other parts are pressed upon as pillars; or, in other words, the pressure acts in the direction of the fibres of the wood. In the old plan, and which, for distinction sake, may be denominated the rectangular mode, the fibres are acted upon transversely, or across the grain, just as a stick, when placed across the knee and pressed by the hands at each end, is first bent and then breaks. To prevent any transverse action upon the fibre of the timber, is one of the benefits arising from the new system, and to impede a longitudinal extension of the structure is another. For as the diagonal frame, composed of a series of triangles, aided by diagonal trussing between the ports, prevents the fabric from being acted upon transversely to the fibres of the materials horizontally placed, so the wales, the planking, the shelf pieces, the improved water ways, and the decks systematically secured, become the tie beams of the structure.

Resulting strength.

(272.) The great strength of the principle here adverted to is also to be contemplated in another point of view—that of rendering the strength of the fabric as general and united as possible. It is a trite maxim to observe that the strength of any body, let its construction be what it may, can never exceed that of its weakest part; but it is one, simple as it is, which has been too often lost sight of in the practice of ship-building. In the new system of Seppings, the openings between the ribs are filled in with slips of timber nearly to the height of the orlop, or lower tier of beams. These being calked and pitched over, make the frame from head to stern, and within a few feet of the greatest draught of water, one compact and water-tight mass of timber; so that were any of the outer planking of the bottom to be removed, the ship would not only continue to float, but would also be preserved from sinking. In the old system, the starting of a plank often proved fatal.

Other sources of strength.

(273.) The openings between the frame, where the width of the space does not exceed three inches, are filled up by driving in wedge-like slices of wood, one driven from the outside, the other from within, forming the parallel space of the opening, and bringing the parts into the closest contact. In the openings exceeding three inches, the space is occupied by corresponding pieces having their fibres laid in the same direction as that of the frame timbers. These fillings add not only to the strength and durability of the fabric, but preserve the health of the crew from the effects of the impure air arising from the filth which so soon collects in these openings, rendering the ship less liable to leakage, as well as facilitating the stoppage of any leak; and lastly increasing the thickness of the bottom from four or four and a half, the usual thickness of the plank, to about sixteen inches, thereby diminishing very considerably the danger to be apprehended from getting on shore, or foundering at sea.

Durability.

(274.) That this improvement promotes the durability of the ship may be inferred from what follows. In the first place, the openings in the old principle, after a ship has had any considerable length of service, are choked up in many parts with an accumulation of filth. Secondly, that no free circulation of air can be obtained in these openings by any means. In the third place, that timber being either freely exposed to, or excluded from the air, is equally preserved. And fourthly, that it has been found on examining the frame and plank of old ships, that those parts now filled in, generally decay sooner than the rest; *viz.* from the floor heads in the midships, and from the dead wood forward and abaft to the height of the orlop clamps.

Gain in the capacity of the hold.

(275.) With regard, also, to the gain in the internal capacity of the hold, it may be remarked, that though the trussed frame projects from the timbers five inches more than the thick stuff at the floor-heads,—yet, as in the old system, the perpendicular riders are brought upon the thick stuff, their projection into the hold is more by eight inches than that of the new, giving an increase of stowage in favour of the diagonal frame. Another important point is, that a tier of iron ballast may also be disposed of many inches lower, giving an increase of stability with less weight, and enabling the vessel to carry her ports higher out of the water.

Bird's-eye view of internal part of a seventy-four.

(276.) In pl. iv. fig. 1. is a bird's-eye view of the internal part of one side of a 74-gun ship in a complete state, the diagonal timbers intersecting the timbers of the frame at angles of about 45°. In the fore part of the ship these timbers are disposed in contrary directions to those in the after part, their distances from each other being from six to seven feet or more; their upper ends abutting against the horizontal hoop, or shelf piece, of the gun-deck beams, and the lower ends against the limber streaks, except in the midships, where they come against two pieces of timber placed in on each side of the keelson for the purpose of taking off the partial pressure of the main mast, which in all cases causes a lagging down of the keel, and sometimes to an alarming degree. Pieces of timber are next placed in a fore and aft direction over the joints of the frame timbers, at the floor and first futtocks heads, their ends being in close contact with and coaked or dowelled to the sides of the diagonal timbers. In this state the framework in the hold presents various compartments representing the forms of rhomboids. A truss timber is then introduced into each rhomboid with an inclination opposite to that of the diagonal timbers, thereby dividing it into two parts. These truss pieces, says Seppings, are to the diagonal frame what the key-stone is to an arch; for no weight or pressure on the fabric can alter its position in a longitudinal direction, till compression takes place at the abutments, and extension of the various ties.

Description.

Diagonal timbers.

Arch-like figure of it.

(277.) This arch-like property of the diagonal frame not only opposes change in a longitudinal direction, but also resists external pressure on the bottom, either from grounding or any other cause, because no alteration of figure can take place, without forcing the several parts of which it is composed into a smaller space. The connection kept up by means of the trussed frame firmly attached to the timbers of the ship by circular coaks and bolts, together with the shelf pieces united to the sides and to the several beams by means of the same sort of

fastenings, imparts such unity to the whole as to give to it an immense superiority over the old system it displaced.*

Shelf pieces.

(278.) The beams of the new system are disposed nearly as in the old, excepting that in midships, where a ship necessarily requires the greatest security, two additional beams have been introduced. All of them are attached to the ship's sides by shelf pieces, or internal hoops, distinguished by the letter E, fig. 2. These shelf pieces are composed of several lengths of timber scarfed or joined together by coaks, or circular dowels, so as to form a kind of internal hoop, extending from the hooks forward, to the transoms abaft, to the underside of which, as well as to the under parts of the beams, they are securely coaked, and being then firmly bolted to the side, instead of becoming a mere local fixture of the beam to the ship's exterior frame, as the knees formerly were, they afford a continued and general security. The shelf piece is also a tie to the top side in a fore and aft direction, co-operating with the trussed frame, as already explained.

Chocks.

(279.) The beams are also secured by chocks, represented in H, fig. 2, placed under all the shelf pieces in the wake of the beams, excepting the orlop, in such a manner as to receive the up and down arm of the iron knees. The lower ends of those under the gun deck shelf piece, step on the ends of the orlop beams, and those of the several decks above, step on the projecting part of the spirketing below. The chocks, particularly those between the orlop and gun decks, admit of their being driven into their respective places very tightly, thereby acting like pillars. Another advantage attending them, is their great tendency to stiffen the ship's side, and to prevent the beam ends from playing on the fastenings when the ship is rolling, or straining under a press of sail.

Iron knees.

(280.) The curved iron plate knees for securing the orlop beams, and the iron forked knees of the other decks, are described in figs. 2 and 3.

Improved decks.

(281.) In the old system of ship-building, the planks of the several decks acted only as mere platforms, or as a cover of a box unconnected with the sides, affording no strength to them whatever. In the new system of Seppings, however, they are so disposed, as not only to oppose an alteration of figure from a force acting on the ship in a lateral direction, but also are made subservient towards securing the beams to the ship's side. The framing and flat of the decks, excepting the quarter deck, forecastle, and round house, which are laid upon the old plan, are disposed as represented in fig. 5. The former, that is, the framing or ledges, and beams are denoted by ticked lines; the latter, or planks by black; those on the starboard side being laid contrarywise to the larboard. The midship ends of the diagonal planks abut against two strakes laid in a fore and aft direction outside the comings of the hatchways; the other ends approaching the timbers of the frame, the butts at each end being secured to a tier of carlings placed for that purpose. The flat or plank of the deck so disposed is connected with a certain number of coaks to the hooks, beams, and transoms. When the decks are thus laid, the waterways described in fig. 2, are brought on and coaked to the ends of the plank. These waterways being then bolted through the ship's sides, and also in an up and down direction, through the flat and shelf pieces, combine the whole in one homogeneous mass of strength.

In what part the weakness of a ship is commonly to be seen.

(282.) A run of three or four years' service most commonly discloses some examples of weakness in the fabric of a ship. These defects, among other places, show themselves at the beam ends, arising in a great degree from the local attachment of the beams to the ship's side, and the flat or covering being entirely unconnected. This imperfect fastening of the extreme ends of the beams, occasions them so to play and work upon the fastening, as often to cut the bolt holes into an oval form by the friction of the bolts. The usual remedy in such a state of things is to load her with additional materials, such as iron knees, standards, breast-hooks, &c.; thus adding greatly to the original weight of the fabric. It is evident that the first gale of wind the ship encounters, after being thus partially strengthened, must again reduce her to her former state of weakness.*

(283.) To remedy defects, whether arising from the decay of the materials, or from any other cause, the principles of Sir Robert Seppings, illustrated in fig. 1, cannot but hold out the most capital advantages; and in no particular is its superiority more manifest than in the decks; for by shifting them when worn too thin for calking, the original connection between the beams, the decks, and the sides will be restored as perfectly as at first.

Other improvements.

(284.) The tendency of the ship to stretch or draw asunder in her upper works, being by no means obviated by the short planks on the inside between the ports, Sir Robert substitutes a truss piece of plank in lieu of them, which being well secured at the abutments, materially aids the trussed frame, and gives great stiffness, thereby opposing any disposition to arch or hog aloft.

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* It has hitherto been very generally believed, says Seppings, that stiffness or inflexibility in a ship is not strength, but that a yielding of the fabric is an essential quality to preserve it from being destroyed by the shocks it sustains. This erroneous opinion must have arisen from another equally incorrect, that a ship must be an elastic body, on account of the elasticity of the materials of which it is composed. It should, however, be remembered, that this elasticity of the materials must be very inconsiderable, since the small degree of elasticity in each piece must necessarily be neutralized in the fabric by the various directions of the parts of which it is composed. Hence a vessel, let her construction be what it may, whether loose or firm, cannot in any case be elastic. It follows also, that the action and reaction of the sea operating upon different parts of the fabric at different times, occasions, on account of the want of unity among the parts, a constant and increasing weakness, which by some may have been mistaken for elasticity.

When a sea strikes a ship forward, continues Seppings, the bow will rise with the sea; which passing aft, lifts the midships in succession, leaving the fore and aft parts with little or no support. Such shocks acting upon a body whose parts are not firmly connected, produce a bending and rebending of the fabric, the planks of the sides playing over each other, and the fastenings becoming strained and loosened by continued repetitions of the acting force. On the contrary, when a body is constructed with such general unity and fixedness of all its parts, that when one is moved the whole fabric must move with it, all the parts of the structure may be fairly said to bear their proper portion of the strain.

* This mode of strengthening ships, as Seppings truly observes, may be compared to that of a raft firmly secured in the first place by strong lashing, which after some time works loose, or rather by working is stretched. As it might be too tedious an operation to secure the raft by retightening the lashing, a small cord would be used for that purpose. It is clear whilst the small cord remains tight, no part of the strain can bear upon the strong but loose lashing, till the other stretches or breaks. So is it with a ship that has additional securities given her without refastening those which had worked or become strained.

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(285.) In fig. 4 the stern of a ship is represented with the trussing and iron work necessary for its security. By this the helm-port transom, which consumes one of the largest and most difficult trees required for a ship, is dispensed with.

Economy is combined with the views of Seppings.

(286.) It is a great principle in these views of Sir Robert Seppings, that not only strength, safety, and durability are so essentially promoted by them, but that economy holds also a capital and prominent place among them. At a time when reduction in our expenditure is so loudly called for, and the Royal Navy cannot be kept up without a large supply of foreign timber, it certainly adds to the credit of this accomplished Naval Architect, that, in a 74-gun ship, upwards of one hundred and eighty oak trees are saved by his masterly combinations, each tree having a load of fifty feet rough contents.

(287.) It must further, also, be borne in mind, that the consumption of large ship timber may be further diminished by the use of inferior and old ship timber, and if old ship timber were generally introduced, as in the case of the Ramillies, one-seventh part of the English oak required for a new 74-gun ship might be saved.

(288.) Another source of economy arises from the greater ease with which the lower part of the ship can be examined, in consequence of the omission of the inside planking. The ease, also, with which any part of the diagonal frame may be replaced, justifies the adoption of fir timber, particularly for the longitudinal pieces and trusses.

Reports made by distinguished officers in favour of these improvements.

(289.) We regret that our limits will not permit more than a brief allusion to the valuable Reports made on the Tremendous, the first ship to which Seppings's principles were applied, by the distinguished officers whose duty it was to make them. They were such as to stamp at once with the highest and best approbation his unrivalled combinations. Of this vessel, it was reported by Mr. Parkin, the master shipwright of Sheerness yard, that the sights on the gun-deck, at the distance of 163 feet, altered 0 in.; that those placed on the upper deck, at the same distance, changed but $0\frac{1}{4}$ in.; and those on the quarter deck and forecastle, at the same distance, altered but $0\frac{3}{4}$ in; after a more than three years' active service, exposed to perilous and turbulent storms. It was also remarked of the same ship, that "the orlop deck beams had not worked on the internal hoop, nor was the crust of the whitewash disturbed; the plates and bolts securing the diagonal riders and terminating under the internal hoop, as well as the heads of the riders, appeared as close as when fayed. The checks fore and aft, bolted under the gun-deck beams for receiving the forked knees, the breast hooks in the gunner's store room, as well as the bolts which fasten the forked knees, none had the slightest appearance of having worked. No appearance of the gun-deck beams having worked on the internal hoop which receives them was to be found; nor any leaks or dampness between the gun-deck water ways, the beams being so perfectly dry, as to have permitted, in many places, the cobwebs to collect between the timbers. The main and gun decks displayed no traces of working, and the same observation was made on the beams of the quarter deck and forecastle; and the whole ship throughout appeared in as perfect a state, as if she had been in dock upon the blocks."

Comparison of three first-rates.

(290.) In the instance, also, of three ships of 120 guns, the Nelson, the St. Vincent, and the Howe, whose forms and dimensions were precisely the same, and whose frames, beams, and external planking were of the same scantlings, it was remarked of the two former, built according to the old plan, and of the latter, built according to the new, that after the first of these vessels was launched, she altered nine inches and a half from her original sheer, and the St. Vincent nine inches and a quarter; but the Howe changed only three inches and five-eighths. The whole machine in the former ships, observes Seppings, was generally disturbed, but the Howe exhibited no such symptoms of weakness.

These useful and important plans objected to.

(291.) No invention or discovery is, however, destined to take its rank in the great catalogue of scientific truths without controversy and dispute; and, perhaps, on the whole, Knowledge is benefited by the furnace it has to pass through. To the inventor, or discoverer, it cannot but be a painful ordeal, but it is the tax he must pay for his celebrity. In the present case it was broadly insinuated that Seppings had borrowed his principles, whereas no application at all resembling his admirable plans can be found in any of the Continental writers on Naval Architecture. The propriety of a different disposition of the materials entering into the construction of a ship, has at different times been suggested by shipbuilders, and partial alterations have in consequence been introduced; but no one, so far as we can trace, has at any time proposed a system of diagonal trussed framing at all resembling that of the great ship-builder adverted to. "If I have received any assistance," he ingenuously observes, "in the progress of this new system, now universally adopted in the British Navy, it was from the plans and drawings of the celebrated bridge of Schaffhausen, and from no other source."

Candour of Sir Robert Seppings.

It was objected that the braces and trusses were applied the wrong way.

(292.) It may be proper, however, to advert to one objection of a practical kind advanced against the new system. It was asserted by some that the braces and trusses applied by Sir Robert Seppings, were disposed in directions precisely the reverse of that which they ought to have been. To meet this objection the following decisive experiment was appealed to.

Experiment with an old 74.

(293.) Early in the year 1817, the Justitia, an old Danish 74-gun ship, was ordered to be broken up on account of her defective state; and Seppings having observed her to be considerably arched or hogged, determined, notwithstanding her age and defective state, to apply the trussing principle to a certain extent, with a view to observe what effect it would produce on a fabric reduced to so weak and shaken a condition.

Description of it.

(294.) The officers of the yard were directed to place sights on the lower and upper gun-decks prior to her being taken into dock; and to ascertain, when she grounded on the blocks, how much she had altered from the state in which she was when afloat. They were then to place a certain number of trusses in the hold, some in the fore part of the vessel inclined forward at about an angle of 45°, and others in the after part of the vessel inclining aft at the same angle. Others were also to be placed at right angles to the former, so as to act against the beams of the deck. In the ports also, other trusses were introduced, those in the ports forward inclining forward in an angle of 40°, and those in the midships aft, at the same angles, but in an opposite direction. As it was uncertain where the centre of fracture would take place, a few of the port-

holes about the centre of the ship had trusses introduced into them in both directions. Wedges were applied to the heels of the trusses to set them tight. The ship being thus partially trussed, the water was let into the dock, and the ship floated out of it into the basin, where she was to lie one hour, when a Committee was to examine the sights, and ascertain how much the ship had altered; and again, what change had taken place in twenty-four hours after floating. This being done, the trusses were to be disengaged in as short a time as possible, in order to observe whether the effect of their removal would be instantaneous or gradual.

Report of the Committee appointed to examine the same.

(295) The following is an extract from the Report of the Committee:—

"When the ship was in dock, on blocks perfectly straight, she came down in the midships, by the sights placed in the gun-deck, two feet two inches and a half; and by those on the upper deck, two feet three inches and a quarter; and when undocked, with the trusses complete and in their places, she hogged, or broke her sheer, by the sights on the gun-deck, one foot two inches and five-eighths; and at the expiration of twenty-four hours she had hogged, or further broke her sheer, two inches and five-eighths, and then appeared stationary and completely borne by the trusses.

(296.) "We then proceeded to take away the trusses in the hold, and when they were wholly disengaged, she further hogged, or broke her sheer, six inches. We next proceeded to take away the trusses in the ports, and when they were wholly cleared, she dropped at the extremities, or further hogged, three inches and a half, and was in that position when tried twenty-four hours after.

(297.) "We further beg to state, that the whole of the trusses alluded to as placed at right angles to the first introduced, slackened as the ship floated from the blocks, and became short from half an inch to three inches and a half, and partook of no part of the pressure; which, in our opinion, clearly proves that the direction in which Sir Robert Seppings has applied his diagonal frame is correct, as also the great utility of the trussing system; for although the ship, from her very defective state, was much against so severe an experiment, it has proved to us its good effects most satisfactorily; for many of the trusses in the ports forced the timbers three-eighths of an inch within the ends of their covering planks, thereby lessening their effect from what it would have been if the ship had been of a sound texture; yet on a ship in this state, the trussing between the ports alone, after those in the hold were wholly disengaged, had the effect of sustaining the immense pressure of both ends of the ship in her worst position, and prevented her from breaking, which she would otherwise have done, from three to four inches, and which she actually and immediately did on their being disengaged."

(298.) This statement of the Portsmouth officers, says Sir Robert Seppings, will, I trust, be considered conclusive as to the benefits to be derived from the principle of trussing in the construction of ships; and although it was only applied from the keelson to the beams in the hold, and not to the ribs or frame of the ship, as is the case when ships are regularly built on this system, yet it sufficiently establishes the soundness of the principle.

(299.) When the Justitia first floated, continues Sir Robert, after being partially trussed, as described, the noise occasioned by the pressure on the trusses is stated to have been truly terrific, until she was fairly settled on them. The disengaging them also caused a similar crash.

Demonstration from abstract principles of the truth of the same.

(300.) A demonstration of the principle employed by Sir Robert Seppings may be seen in the XLIId Number of the *Journal of the Royal Institution*. If through the point in which the sustaining forces meet, a line be drawn to represent the measure and direction of the straining force, and on it a parallelogram be constructed, as a diagonal, having its sides parallel to the sustaining forces; then if the remaining diagonal of the parallelogram be drawn, and through the point where the sustaining forces meet, another line parallel to the same, all the parts of the framing on *the same side* of this line, as the straining force, will be in a state of *compression*, and all those on the other side of the same line in a state of *extension*. Applying this principle to fig. 7 and 8, plate iii., we shall deduce the results contained in the following Table.

	Nature of the Strain operating on the Timbers.				
	Braces.	Trusses.	Upper longitudinal piece.	Middle longitudinal piece.	Lower longitudinal piece.
With the braces in the fore body inclined aft, and those in the after body inclined forward as in fig. 7.	Extension.	Compression.	Extension.	Compression.	Compression.
With the braces in the fore body inclined forward, and those in the after body inclined aft, as in fig. 8.	Compression.	Extension.	Extension.	Extension.	Compression.

The primary object of the diagonal framing is to prevent arching; and if we suppose A F, in both figures, to represent the neutral line from which the arching proceeds towards both extremities, it is evident that it is the mechanical combination represented in fig. 7 which can alone prevent it. For since A, in that figure, by the hypothesis, is one of the neutral points of the system, it may be regarded as fixed; and the tendency of arching being to depress the points H, C and G, B, the effect on the braces A C and A B will be precisely similar to the weights applied in the preceding investigation; that is, to produce extension, and which is effectually provided for by the fastenings. The effect, moreover, brought at the same time into action by the trusses, in consequence of the disturbing force, is to resist, by the whole longitudinal strength of their fibres, all tendency to alteration of form; so that the effect exerted to depress the point C, is at once resisted by the fastenings appertaining to the brace A C, and to the longitudinal strength of the fibres of the truss proceeding from the unchangeable point F. The point E becoming, in this point of view, fixed, the action of the force which tends to depress the point H, in common with the point C, is resisted by the fastenings of the longitudinal timber A H, and by the longitudinal resistance of the fibres of the truss F H; so that, provided the fastenings of the braces and of the upper longitudinal timber are sufficient, and the abutments of the trusses and of the middle longitudinal timber are also proper, all tendency to arching will be resisted in proportion to the perfection of the materials, and the excellence of the workmanship.

(301.) But by referring to the converse disposition of the braces, as represented in fig. 8, it appears, from the preceding investigation, that the braces A C and A B are subject to compression. And since the point A is, by the hypothesis, the neutral or fixed point, the effect of the compression of the brace A C must be to depress the point C, and thus to promote the tendency to arching. Nor is this tendency to lower the point C prevented by the action of the truss F E; since the point F being fixed by the supposition, the tendency to extension which takes place in the truss must lower the point E, and thus promote the further declension of the point C. The point E being thus depressed, must add its effect to the extending force called into action in the truss E H, and thus produce a declension in the point H. Hence the whole effect of the disturbing force is to lower every part of the frame from C to H, and thus to promote the arching of the vessel. Hence the superiority of the present system of diagonal framing becomes apparent, and the advantages derived from it are demonstrated by the small alteration of form which ships now undergo in the act of launching.

More particular allusion to the causes of arching.

(302.) It is proper, however, to advert more particularly to some of the causes of arching, and in the first place to the condition of weight. There is a well-known and obvious inequality of the distribution of the weight and pressure, which, independently of all circumstances of construction, produce arching. It is possible, as Dr. Young observes, there may be cases in which a strain of a very different nature is produced, but in ships of war this tendency is universal. It is, however, very different in degree in the different parts of a ship; and of course, still more different according to the different modes of distribution of the ballast and stores occurring in different ships. In a modern 74-gun ship, fitted for sea, the length being 176 feet, and the breadth $47\frac{1}{2}$, the forces in ordinary cases are thus distributed:

Investigations of Dr. Young.

	Feet.	Weight in Tons.	Pressure in Tons.	Difference in Tons.
Aftermost.	49	699	627	+ 72
Next	20	297	405	− 108
....	50	1216	1098	+ 118
....	20	290	409	− 119
....	37	498	461	+ 37
	176	3000	3000	00

Distribution of forces.

(303.) Now although this general distribution of the forces may be supposed to exist, the laws of equilibrium will not allow us to suppose them to be concentrated in the middle of the respective portions, or equally distributed throughout them, still it is natural to suppose the excesses of weight and pressure to be arranged with as few abrupt changes as possible, in order that they may neutralize each other at the common termination of the adjoining portions, and to become more unequal in parts more remote from these neutral points. Thus the excess of weight in the first 49 feet being 72 tons, it may be supposed to begin at the rate of $\frac{144}{49}$ tons per foot, and to diminish gradually and equally, so that its centre of action will be at the distance $\frac{49}{3}$ from the end. The excess of pressure must increase in the next place, until, at the distance of 59 feet from the stern, it becomes $\frac{108}{10}$ per foot, and then diminish until it vanishes at 69, where the excess of weight must begin to prevail, becoming at 94, $\frac{118}{25}$ per foot, and vanishing at 119. The excess of pressure might then be supposed to increase gradually through the next portion, in order to avoid an abrupt change at its extremity; but this supposition would still be insufficient, and it becomes necessary to imagine that for 6.6 feet the forces remain neutralized, and the pressure then prevails, so that its excess becomes at last $\frac{119}{6.7} = 17.7$ per foot. It must then decrease for 17.5 feet, and the excess of weight at the extremity must become 19.7 feet, the neutral point being at 156.5. The equilibrium of the forces will then be expressed by the equation

$$72 \times 16.3 - 108 \times 59 + 118 \times 94 - 119 \times 134.5 - 155 \times 144.8 + 192 \times 169.5 = 0,$$

which Dr. Young imagines is sufficiently accurate for every purpose.

Determination of the strain for each point.

(304.) From this distribution of the forces, we obtain a determination of the strain for each point of the respective portions, which is in the joint ratio of the magnitudes and distances of all the forces concerned, on either side of the point, reduced into a common result. For the first portion it is

$$\frac{72}{49}x^2 - \frac{1}{6} \cdot \frac{144}{49} \cdot \frac{x^3}{49},$$

x being the distance from the stern.

For the second,

$$72\,(x-16\tfrac{1}{3})-\frac{1}{6}\cdot\frac{108}{10}\cdot\frac{(x-49)^3}{10}.$$

For the third,

$$72\,(x-16\tfrac{1}{3})-54\,(x-55\tfrac{2}{3})-\frac{108}{20}\,(x-59)^2+\frac{1}{6}\cdot\frac{108}{100}\cdot(x-59)^3.$$

For the fourth,

$$72\,(x-16\tfrac{1}{3})-108\,(x-59)+\frac{1}{6}\cdot\frac{118}{25}\cdot\frac{(x-69)^3}{25}.$$

For the fifth,

$$72\,(r-16\tfrac{1}{3})-108\,(x-59)+59\,(x-94)+\frac{118}{50}\,(x-94)^2-\frac{1}{6}\cdot\frac{118}{25}\cdot\frac{(r-94)^3}{25}.$$

For the sixth, from 119 to 125.6,

$$72\,(r-16\tfrac{1}{3})-108\,(x-59)+118\,(x-94).$$

For the seventh,

$$72\,(x-16\tfrac{1}{3})-108\,(x-59)+118\,(x-94)-\frac{1}{6}\cdot\frac{119}{13.4}\cdot\frac{(x-125.6)^3}{13.4};$$

and in the last 37 feet, the strain will be expressed by

$$(176-x)\,19.7\times\tfrac{1}{2}(176-x)-\frac{1}{6}\cdot 19.7\,\frac{(176-x)^3}{19.5}.$$

Hence we find the strain, at seven points, 22 feet distant from each other and from the ends, 605, 1993, 2815, 2244, 2655, 4610, and 1875; and by taking the differential of x in the seventh portion, we determine he maximum at $141\tfrac{1}{3}$ feet, amounting to 5261 tons, supposed to act at the distance of one foot.

Curve produced by such a strain.

(305.) In order to form an idea of the curve which would be produced by such a strain, acting on a uniformly flexible substance, we may consider the curvature as represented by the second fluxion of the ordinate y; and by finding and correcting the fluent separately for each portion, we may obtain the ordinate, or fall, at any given point corresponding to a given extent of arching of the whole fabric. It will, however, be sufficiently accurate for this purpose, to consider the forces as concentrated in a limited number of points, dividing those which act in the extreme portions into two parts, in order that the curvature may be continued to the ends; so that the whole of the forces may be thus distributed.

	Distances.	Forces.
At	0	+ 36
	$32\tfrac{2}{3}$	+ 36
	59	− 108
	94	+ 118
	134.5	− 119
	144.8	− 155
	163	+ 96
	176	+ 96

The strain for each portion may then be represented by $a - bx$, whence

$$\ddot{y} = a x \dot{x} - b x x \dot{x},$$

$$\dot{y} = a x \dot{x} - \frac{1}{2} b x^2 \dot{x} + c \dot{x},$$

and $$y = \frac{1}{2} a x^2 - \frac{1}{6} b x^3 + c x + d.$$

Dr. Young remarks it will be most convenient, in calculation, to make x begin anew with each portion, setting out from the middle, and to divide the numbers by 100, in order to shorten the operations. Thus, for the middle portion, from 88 to 59, the strain will be $.2028 + .36\,x$, a being $.2028$, and $b = -.36$; and when x becomes $.22$, y is $.00552$; and when $x = .29$, $\frac{\dot{y}}{\dot{x}} = .0740$, and $y = .0011$; which values being substituted in the equations for the next portion, we have $c = .074$, and $d = .0011$. By going through the whole length in this manner, we find the fall at the extremes, and at seven equidistant intermediate points, to be,

.08697
.05325
.02514
.00552
.00000
.00507
.02531
.06705
.12325.

If we wish to find the point at which the curve is parallel to the chord of the whole, we must inquire where $c = (.12325 - .08697) : 1.76$, which will be at 98 feet, or 10 feet before the midships.

Effects of pressure in a longitudinal direction

(306.) To the strain which the circumstances of weight and upward pressure produces, another must be added resulting from a cause, which, although not very inconsiderable, appears to have been altogether neglected before Dr. Young inquired into it; and this is, that partial pressure of the water in a longitudinal direction, affecting the lower parts of the ship only, and tending to compress and shorten the keel, while it has no immediate action on the upper decks. The pressure thus applied, must obviously occasion a curvature, if the angles made with the decks by the timbers are supposed to remain unaltered, while the keel is shortened in the same manner as any soft and thick substance, pressed at one edge between the fingers, will become concave at the part compressed. This strain, upon the most probable supposition respecting the comparative strength of the upper and lower parts of the ship, must amount to more than one-third as much as the mean value of the former, being equivalent to the effect of a weight of about 1000 tons, acting on a lever of one foot in length, while the strain, arising from the unequal distribution of the weight and displacement, amounts where it is greatest, that is, about 37 feet from the head, to 5260; and although the strain is considerably less than this exactly in the middle, and throughout the aftermost half of the length, it is no where converted into a tendency to "sag," or to become concave. It must, however, be remembered, that when arching actually takes place from the operation of these forces, it depends upon the comparative strength of the different parts of the ship and their fastenings, whether the curvature shall vary more or less from the form, which

results from the supposition of a uniform resistance throughout the length.

(307.) Our limits will not permit us to pursue the analytical conditions connected with this longitudinal pressure; and we can, therefore, only add that these different causes of arching being independent of each other in their operation, their effects will be simply united into a common result. Hence the whole curvature of the ship, supposing its strength equable throughout its length, may be thus represented.

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Numerical results of the whole curvature of a ship.

Distance from the stern	0	22	44	66	88	110	132	154	176
Strain.............	1247+0	605	1993	2815	2224	2655	4610	1875	0
Fall	.04828	.02716	.01207	.00302	.00000	.00302	.01207	.02716	.04828
	.08697	.05325	.02514	.00552	.00000	.00507	.02531	.06705	.12325
	.13525	.08041	.03721	.00854	.00000	.00809	.03738	.09421	.17153
For 12 inches of arching	10.58	6.29	2.91	.67	.00	.63	2.93	7.37	13.42

Force of the wind and waves.

(308.) Important as are the effects produced on the framework of the hull, when it floats quiescently on the water, their amount is greatly increased when it is exposed to the forces of the wind and waves. The effect of the wind, Dr. Young observes, is generally compensated by a change of the situation of the actual water line, so that its amount may be estimated from the temporary or permanent inclination of the ship; and the force of the waves may be more directly calculated from their height and breadth. As a fair specimen of the greatest strain likely to arise from the waves in any common circumstances, we may consider the case of a series of waves 20 feet in height, and 70 in breadth, their form being such, that the curvature of surface may be nearly proportional to the elevation or depression.

How strains arising from waves may be computed.

The strain produced by the pressure of waves of given magnitude, may be calculated from the comparison of the displacement with respect to their surface, with the displacement with respect to a level surface. It is hence found that the greatest strain takes place in a 74-gun ship, at the distance of about 18 feet from the midships, amounting to about 10,000 tons, at the instant when the ship is in a horizontal position, while, in more common cases, when the waves are narrower, the strain will be proportionally smaller and nearer to the extremity. Hence it appears, that the strain produced by the action of the waves may very considerably exceed in magnitude the more permanent forces derived from the ordinary distribution of the weight and pressure; so that when both strains cooperate, their sum may be equivalent to about 15,000 tons acting on a lever of one foot, and their difference, in opposite circumstances, to about 5000. There may, Dr. Young further observes, possibly be cases in which the pressure of the waves produces a still greater effect than this; and it may also be observed, that the agitation accompanying it tends to make the fastenings give way much more readily than they would do if an equal force were applied less abruptly. At the same time, it is not probable that this strain ever becomes so great, as to make the former perfectly inconsiderable in comparison with it, especially if we take into account the uninterrupted continuance of its action: it appears, therefore, to be highly proper that the provision made for counteracting the causes of arching should be greater than for obviating the strain in the contrary direction; for example, that if the pieces of timber intended for opposing them were, on account of the nature of their fastenings, or for any other reason, more capable of resisting compression than extension, they should be so placed as to act as shores rather than as ties; although it by no means follows, from the form which the ship assumes after once breaking, that the injury has been occasioned in the first instance by the immediate causes of arching; since, when the fastenings have been loosened by a force of any kind, the ship will naturally give way to the more permanent pressure which continues to act on her in the state of weakness they superinduced.

Breaking transversely.

(309.) The pressure of the water against the sides of a ship has also a tendency to produce a curvature in a transverse direction. This is, moreover, greatly increased by the distribution of the weight, the parts near the sides being the heaviest, while the greatest vertical pressure of the water is in the neighbourhood of the keel. This pressure is often transmitted by the stanchions to the beams, so that they are forced upwards in the middle; when they are unsupported, the beams are more generally depressed in the middle, by the weight of the load which they sustain; while the inequality of the pressure of the water cooperates with other causes in promoting the separation of the sides of the ship from the beams of the upper decks. On the other hand, Dr. Young observes, the weight of the main mast often prevails partially over that of the sides, so that the keel is forced rather downwards than upwards in the immediate neighbourhood of the midships. The tendency to a transverse curvature is observable, when a ship rests on her side, in the opening of the joints of the planks aloft, and in their becoming tighter below; although this effect depends less immediately on the absolute extension and compression of the neighbouring parts, than on the alteration of the curvature of the timbers in consequence of the pressure.

Lateral curvature.

(310.) Under such circumstances, there is, moreover, a tendency to produce a lateral curvature, and shores are sometimes employed to prevent its effects, when a ship is "hove down" on her side. This, indeed, is comparatively a rare occurrence; but when large waves strike a ship obliquely, they must often act in this manner with immense force. The elevation on one side may be precisely opposite to the depression on the other, and the strain from this cause can scarcely be less than the vertical strain already calculated. Its effects, however, are less commonly observed, because we have not the same means of ascertaining the weakness which results from it, by the operation of a permanent cause. When a ship possesses a certain degree of flexibility, she may in some measure elude the violence of this force by giving way a little for the short interval occupied by the passage of the wave; but her sailing in a rough sea must be impaired by such a temporary change of form.

Investigations of Dupin on arching.

(311.) Dupin, in a Paper in the *Philosophical Transactions* for 1817, has investigated the analytical conditions of arching. By representing by x the distance of any part of a vessel from a vertical plane, and

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by dx the thickness of the infinitely small sections parallel thereto, $\phi(x)\,dx$ denoting the weights of those sections, and $\psi(x)\,dx$ that of the water which they respectively displace, the integral of the total moment of the forces will be

$$\int\{x\phi(x)\,dx - x\psi(x)\,dx\}.$$

Now, in order that this function may be either a maximum or a minimum, its variation must be zero, and hence we have

$$\delta\int\{x\phi(x)\,dx - x\psi(x)\,dx\} = 0.$$

In this latter expression, however, neither of the original sections alters its weight; and the functions $\phi(x)$ and $\psi(x)$ remain constant, as well as the thickness dx of the sections, only by removing the plane, with respect to which the moments are taken, to the distance δx, the section of which $\phi(\delta x)$ represents the weight, and $\psi(\delta x)$ its displacement. Hence we have

$$0 = \delta\int\{\phi(x) - \psi(x)\}\,x\,dx$$
$$= \int\{\tfrac{1}{2}[\phi(\delta x) - \psi(d x)] + [\phi(x) - \psi(x)]\}\,dx\,.\,\delta x.$$

But since the functions $\phi(x)$ and $\psi(x)$ become zero, when we cause x to vanish, these expressions represent the weight and displacement of a vanishing section; and hence we see that $\phi(\delta x) - \psi(\delta x)$ becomes infinitely small when compared with $\phi(x) - \psi(x)$.

If, therefore, the expression $\phi(\delta x) - \psi(\delta x)$ may be neglected, much more may the function

$$\tfrac{1}{2}[\phi(\delta x) - \psi(\delta x)]\,dx\,.\,\delta x;$$

and hence the general expression representing the condition of either the maximum or minimum of the moments tending to produce arching will be

$$0 = \delta x\int\{\phi(x) - \psi(x)\}\,dx,$$

where $\int\phi(x)\,dx$ is the total weight of the sections under consideration, and $\int\psi(x)\,dx$ the total weight of the displacement of the same sections.

(312.) Hence we learn, that the sum of the moments tending to produce arching, is either a maximum or a minimum, when the weight of the part of the vessel, either before or behind the plane of the moments, is equal to the weight of the water displaced by the same part of the ship.

(313.) The maximum condition may be distinguished from that of the minimum, according as the term of the formula neglected has the *same* or a *contrary* sign from the function of the total moment

$$\int\{\phi(x) - \psi(x)\}\,x\,.\,dx,$$

and the sum of the moments, with relation to the plane determined, will be a *minimum* or a *maximum*.

Since, however, $\phi(\delta x)\,\delta x$ is the weight of the section having δx for its thickness, and $\psi(\delta x)\,\delta x$ the weight of the water displaced by the same section, the function

$$\tfrac{1}{2}[\phi(\delta x) - \psi(\delta x)]\,\delta x\,.\,dx$$

will be positive or negative, according as the weight of the infinitely small section commencing at the plane of the moments, is greater or less than the weight of the water displaced by the section itself. Hence Dupin deduced the following general theorems.

General theorems.

I. *That when a vertical plane divides a vessel into two parts, so that the weight of each part is equal to the weight of water displaced by it, the moments of those parts estimated in relation to the same plane, to produce what we have denominated arching, will be either a maximum or a minimum.*

II. *That this effect will be a maximum, when the infinitely small section contiguous to the plane of the moments, has its own moment in a contrary direction to that of the total moment.*

III. *That the effect will be a minimum when this section has its own moment acting in the same direction as the total moment.*

Applications of these theorems to Dr. Young's forces.

(314.) In order to apply these theorems to the system of forces adopted by Dr. Young as representing the conditions of the 74-gun ship before alluded to, Dupin assumed a line A O, fig. 9, coincident with the water's surface, and in it certain segments, A C, C E, E G, G H, H K, K M, and M O, corresponding to the quantities in the first of the following columns. On certain of these segments he supposed triangular areas to be formed equivalent to the differences between the weights of the sections and their displacements as estimated by Dr. Young. For instance, on the segment A C he formed the right-angled triangle A B C = + 72, below the water line, because the weight exceeded the pressure. On C E, also, he reared the isosceles triangle C D E = − 108, and above the same line, because the pressure in this case exceeded the weight. On E G, likewise, he formed a triangle, E F G = + 118; on H K the right-angled triangle, H I K = − 119; and lastly on K M, M O the right-angled triangles I K M, M O N, the former having an area of − 155, and the latter of + 192, the difference being + 37.

Values of the Segments making up the total Length of A O of the Ship.	Areas equivalent to the Differences between the Weights of the Sections and their Displacements.
A C = 49	Surface A B C = + 72
C E = 20	Surface C D E = − 108
E G = 50	Surface E F G = + 118
G H = 6.6	
H K = 13.4	Surface H I K = − 119
K M = 17.5	Surface I K M = − 155
M O = 19.5	Surface M N O = + 192
Total A O = 176	Total = 000

(315.) Now, after determining the centres of gravity of the several triangular areas here referred to, and letting fall perpendiculars from them on the primitive line A O, he obtained an equation of equilibrium identical with that given by Dr. Young. On this equation Dupin makes many judicious observations. In the first place, he remarks, that the triangle E F G ought not to be regarded as isosceles, since its vertex is the point in which the difference between the weight of the section and its displacement, is the greatest in this part of the vessel, and which ought to correspond with the position of the main mast. But the main mast is situated abaft the middle point ⊕ of the vessel, and is, therefore, nearer the common point of origin A by 19 feet $\left(=\frac{176}{2} - 69\right)$ than the central part of the ship. The learned Frenchman thinks the vertex of the triangle C D E to be too far forward by at least 13 feet. To make the sum of the moments vanish also, Dr. Young was obliged to transfer a weight of 37 tons from the fore part of the ship to its displacement.

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Correction of the hypothesis of Dr. Young.

(316.) To correct the hypothesis of Dr. Young, and apply the theorems just investigated to the maximum and minimum sections, Dupin drew within the triangle C D E a line P p, so as to cut off from it the negative area C D P p, numerically equal to the area of the triangle A B C. Since, therefore, the area of the trapezium C D P p is by this supposition $= -72$, it follows that the area of P p E $= -36$; and similar triangles being to each other in the duplicate ratio of their homologous sides, we have

$$\Delta D d E : \Delta P p E :: d E^2 : p E^2,$$

or $$-54 : -36 :: 10^2 : \frac{-36 \times 10^2}{-54}.$$

Hence

$$p E = 20 \sqrt{\frac{1}{6}} = 8.15;$$

and, consequently,

$$A p = A E - p E = 60.85.$$

If we now take the moments of the triangle A B C, and the trapezium C D P p = Δ C D E $-$ Δ P p E, with respect to the line P p, in which case we shall have for the positions of the centres of gravity

$$p b = A p - A b = 60.85 - 16.3 = 44.55,$$
$$p d = d E - p E = 10 - 8.15 = 1.85,$$
and $$\frac{1}{3} p E = \frac{8.15}{3} = 2.72;$$

and hence for the moments required the following results:

$$44.55 \times +72 = +3207.6$$
$$1.85 \times -108 = \quad -199.8$$
$$2.72 \times -36 = \quad -97.8,$$

which gives for the final moment the positive quantity 2910, indicating the tendency by which the stern of the vessel falls.

(317.) If, however, in conformity to the second theorem, we find that the moment of the infinitely small section contiguous to the plane of the moments here referred to, be of a contrary character to that of the definitive moment just deduced, we shall be justified in concluding that the moment 2910 is absolutely the greatest that can be discovered; and that the moment of the infinitely small section alluded to is *negative* is apparent, on account of its partaking of the general condition of the triangle C D E, which has all its sections of a *less* weight than the volumes of water they respectively displace, whereas the total moment by the preceding calculation is clearly *positive*.

(318.) Let us now consider the conditions of the sections comprised between the points E and G; and since the area of the triangle E F G is by the hypothesis greater than the area of the triangle E p P, let us suppose a line Q g to be drawn at right angles to the water's surface, so as to cut off the triangle Q g E equal to the triangle E p P. To fix the position of this line, we have, by means of the similar triangles F f E, Q g E, the following proportion:

$$\Delta F f E : \Delta A g E :: E f^2 : E g^2,$$

or $$59 : 36 :: 25^2 : \frac{36 \times 25^2}{59}$$

Hence

$$E g = 150 \sqrt{\frac{1}{59}} = 19.5,$$

and, consequently,

$$A g = A E + E g = 88.5.$$

(319.) In order to estimate the moments of the triangles A B C, C D E, Q g E, with regard to the line Q g, we shall have for the positions of the centres of gravity,

$$g b = A g - A b = 88.5 - 16.3 = 72.2$$
$$d g = A g - A d = 88.5 - 59 = 29.5$$
$$\frac{1}{3} E g = \frac{19.5}{3} = 6.5,$$

and for the moments required,

$$72.2 \times +72 = +5196$$
$$29.5 \times -108 = \quad -3186$$
$$6.5 \times +36 = +234,$$

giving for the final moment the positive quantity 2244.

(320.) If now we consider the nature of the sections which are infinitely near Q g, it will be perceived that their weights exceed their displacements, and that their tendency, hence, is to produce a degree of curvature in the ship analogous to the moment just determined. Hence the moments tending to arch the ship longitudinally in Q g, at the distance of 88.5 feet aft, must by the theorem be a *minimum*.

(321.) In the next place, let us consider the nature of the sections situated between the points H and M. The displacement of these sections exceed their absolute weights by a quantity equivalent to $+155 - 119$, this amount being greater than the total result

$$+72 - 108 + 118.$$

Hence it is evident that we must cut off from the triangle H I M, by means of a vertical line R r, such a triangle H R r as may make

$$A B C + E F G - G D E - H R r = 0,$$

and which condition furnishes for the value of the area of the triangle sought

$$H R r = A B C + E F G - C D E$$
$$= 72 + 118 - 108$$
$$= 82.$$

Hence

$$\Delta H I K : \Delta H R r :: H K^2 : H r^2,$$

or

$$119 : 82 :: 13.4^2 : \frac{82 \times 13.4^2}{119}.$$

Whence

$$H r = 13.4 \sqrt{\frac{82}{119}} = 11.21,$$

and $$A r = A H + H r = 125.6 + 11.21$$
$$= 136.81.$$

(322.) To obtain the moments of the triangles A B C, C D E, E F G, and H r R with regard to the line R r, we shall obtain for the positions of the centres of gravity

$$r b = r A - A b = 136.81 - 16.3 = 120.51$$
$$r d = r A - A d = 136.81 - 59 = 77.81$$
$$r f = r A - A f = 136.81 - 94 = 42.81$$
$$\frac{1}{3} r H = \frac{11.21}{3} = 3.74;$$

and hence for the moments themselves

$$
\begin{array}{lll}
120.51 \times +\ 72 = + 8676.72 & & \\
77.81 \times -\ 108 = & & -\ 8403.48 \\
42.81 \times +\ 118 = + 5051.58 & & \\
3.74 \times -\ 82 = & & -\ 306.68
\end{array}
$$

giving for the definitive moment, the positive number 5018.14.

(323.) Thus the sections infinitely near to R r, will have their weights less than the resistance of the water they displace, the moments of the same sections acting in a contrary direction to that of the total moment. Hence, by the second theorem, the moment just deduced is a *maximum*.

(324.) At the extremities of the vessel, the sum of the moments being zero, must furnish likewise two minimum values. Hence the *maximum* and *minimum* values of the moments tending to arch the vessel are those in the following Table :

Naval Architecture.

At zero, or the point A.	At A p = 60.85 feet from A.	At A q = 88.53 feet from A.	At A r = 136.81 feet from A.	At A o = 176 feet from A.
Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
Value of the moment = 0.	Value of the moment = 2910.	Value of the moment = 2244.	Value of the moment = 5018.44.	Value of the moment = 0.

(325.) If we refer to the *maximum* and *minimum* sections passing through A p and A q, we perceive that from the former to the latter there must be a continual declension in the value of each moment; and that, consequently, at 88 feet from the origin at A, the magnitude of the moment must be greater than at the distance of 88.53 feet from the same point where the minimum section exists; a conclusion, it may be remarked, agreeing with the theory of Dr. Young. So, also, by referring to the *maximum* sections deduced by Dupin we shall find them greater than the sections nearest to them in the investigation of Dr. Young.

(326.) Similar analogies, however, do not exist, when we compare the *maximum* section of Young with the deductions of Dupin. The former makes that section to exist at the distance of 141.3 feet from the after part of the water line, producing a strain equivalent to 5261 tons acting at the distance of a foot; whereas the latter estimates the strain at a like point at 4920.3 tons. These investigations are far, however, from being perfect. Observation joined to future applications of analysis will be necessary to render it perfect.

(327.) It has been very ingeniously observed, says Dr. Young, that arching is not only a part of the evil occasioned by a ship's weakness, but that it has an immediate tendency to afford a partial remedy for the cause which produces it, by making the displacement greater at the extremities of the vessel, and smaller in the middle; but, in fact, this change appears to be too inconsiderable in its extent, to produce any material benefit, the strain at the midships being diminished by each inch of arching only 66 tons, supposed to act at one foot; so that very little relief is obtained from the change, in comparison with the whole strain.

Chapman's views of arching.

(328.) What the views of Chapman were respecting the trussing of ships may be gathered from the following extract from his Work on ships of war, and by which it will be seen how much superior the views of Seppings were to those of the Swedish ship-builder.

(329.) If a ship were cut transversely into numerous parts, and each part were enclosed at its ends, so as to be water tight, those parts nearest the extremities of the ship would sink much deeper, and the middle parts rise higher out of the water, and thus assume a different form from that shown in the drawing, namely, higher in midships and lower at the extremities. And as the form of a ship above or below the water cannot be otherwise than it is now, and always has been, nor can the situation of the weights by which the ship is pressed down be altered, this defect can be obviated in another manner than by a certain security through the whole length of the ship, not, however, wholly, but, in a greater or less degree, depending on using the best means, and those which cause the least inconvenience.

(330.) In the year 1759 two vessels were built at Stralsund, to be used in the Frische-haf, in a War with the King of Prussia, the one about 100 feet long, and above 20 feet in breadth, and drawing not more water than $7\frac{1}{2}$ feet: the other about 80 feet in length, and drawing $5\frac{1}{2}$ feet water. They carried heavy armaments, especially at the extremities, and were made to row as well as sail; and on account of this armament and many considerable weights, a strong combination of the fabric was necessary; but although their bottoms had the greatest fulness which could be reasonably allowed to them, they could not thereby obtain a sufficient displacement. It was therefore necessary to build them with timbers of as small scantling as possible; and as on this account they could not possess the necessary strength, especially in regard to their arching, the following method was adopted.

(331.) Parallel to the middle line of the vessels on each side, about half way between the keelson and the orlop clamps, a strake of oak was laid on its edge six inches thick, along the whole length of the hold, let down an inch over all the timbers, the ends of which extended to the deck, both forward and abaft, which was called the builge-strake, and which was fastened with bolts through the timbers and outside plank. Under the beams of the deck, perpendicularly over the builge-strake, was fixed on its edge a strake of fir along the whole length of the vessel six inches thick, with a score one inch deep for the beams, to which it was bolted, and was called the longitudinal shelf. Both ends of this shelf lay against the timbers of the frame, and its lower side on the builge-strake, to which it was coaked, both forward and abaft, and was fastened with bolts through the builge-strake, timbers, and outside

plank. Between the builge-strake and the shelf, vertical oak pillars were placed, at a distance from each other equal to their length; from the lower end of one pillar to the upper end of each following pillar was placed a diagonal shore of fir. See more on this subject in the *Architectura Navalis Mercatoria*, printed at Stockholm in the year 1768, and in the Treatise on Ship-building relating to it, printed at Stockholm in the year 1775, p. 217; and as it was found that the object was obtained by the use of this diagonal trussing, all armed vessels, as well great as small, have had trussing in all respects similar to it.

(332.) In the year 1772 an armed vessel was built at Stockholm about the same size as that first named, but instead of the vertical pillars being of oak, as in the former vessel, they were of fir, but in all other respects as before. Immediately the vessel was off the slip it was found that it had straightened in the launching four inches, but within twenty-four hours it recovered so much of its former sheer, that the sheer was straightened by only two inches. When it was examined in what manner this had taken place, it was found that the abutments of the shelf had pressed into the vertical fir pillars, nearly half an inch in some and it was this yielding of the timber, which in some, degree recovered itself, by which the arching was diminished. On the lower ends of the pillars against the wedges little or no indentation was observed. The sliding plank on which the builge-ways ran, during the launching, did not extend to the edge of the water, but terminated about a foot above it, so that when the middle of the vessel was at the end of the sliding plank, its foremost end had not the support of the water, and became balanced; and it was just at this moment that the arching must have taken place.

(333.) About the year 1789 two larger vessels were built, each carrying one tier of 36-pounders, but without any diagonal trussing. They were used in the Russian war, and became much arched, and when they afterwards required a large repair, it was found that the keel, which was 135 feet in length, had curved upwards in midships $2\frac{1}{4}$ feet, on which account the usual diagonal trussing in the hold was given to them.

(334.) Suppose it be required, says Chapman, to make a similar disposition of security for a ship of the line, for instance, a ship of 110 guns, and let fig. 10 and 11 represent this arrangement. As this strengthening should be applied at the place most convenient in respect to the stowage of the hold, it is most important to obtain a sufficient breadth for a certain number of water-casks, here considered to be four whole and one half cask on each side the keelson or midship pillars. If five whole casks were taken, the trussing would come too far out into the builge. The nearer it comes, also, to the middle of the ship the greater effect it has in preventing arching; therefore, when the diameters of four whole and one half cask are added together, with half the thickness of the midship pillar, and the whole thickness of the diagonal shores, it gives $18\frac{3}{4}$ feet, which is the distance of the middle line of the ship from the outside of the diagonal shores. To show this trussing, the ship's side, from one end to the other, as far as this trussing extends, is supposed to be laid open. *a* is the frame timbers, *b* the ceiling, *c* the riders, *d* the builge-strake, *e* the fillings between the riders, builge-strake, and ceiling, *f* the shelf under the beams, which being two thicknesses in breadth, are bolted together to give shift to each other. Over these are laid three strakes of deck plank of such a thickness that they can be let down one inch over the beams, with bolts through these beams and the shelf. *g* is the vertical pillar, and *h* the diagonal or shore. In other respects the disposition of the pillars and trusses, &c. is as already described.

(335.) It must be further remarked, that all the parts which belong to this trussing, and terminate at the extremities of the ship, are there secured in the best manner to the ship: therefore not only must the ends of the builge-strake and shelf be coaked together at the extremities of the ship, but also the security there required is supplied by fillings lying longitudinally, which are not only coaked together but also to the builge-strake and shelf; and which extend as far as where the shelf and builge-strake are about 2 or $2\frac{1}{2}$ feet apart, by which the whole mass, namely, the shelf, filling, builge-strake, timbers, and outer plank, receive a sufficient number of bolts, which are driven from without and within, as *xx*. Likewise the fillings *e* under the builge-strake and between the riders are coaked to the ceiling, and the builge-strake to the fillings *e*. The combination of this disposition of trussing at both extremities of the ship cannot always, however, be performed in the same manner. For example, if the trussing comes nearer to, or further from, the middle line of the ship, or if the ship has greater or less fulness at the extremities, &c., each of these cases requires a different method, the circumstance of the part to be strengthened determining the manner of performing it.

(336.) This method of security, when it is well executed, will certainly accomplish the object. That the preventing arching is of consequence may be inferred hence. When a coasting vessel, which was to carry a considerable armament, and more than 100 feet long, was strengthened in this manner, the day before it was launched, the wedges at the lower ends of the pillars were for the last time driven up. When all the wedges at the pillars fore and aft on both sides were hardened up at the same time, the upper end of the keel rose so much from the upper block, that the block became loosened and movable. It should also be remarked, that this vessel was not deep in the hold, had only one deck, with light upper works and small scantlings.

(337.) As the timber and iron work required for this trussing would be equal to the weight of 1200 cubic feet of water, the three-decker would sink about $1\frac{1}{2}$ inch deeper in the water, by which the height of the battery would be so much the less; but as this should not be allowed, the drawing should be altered, so that the displacement, which is $=152{,}875$, may become $=154{,}075$ cubic feet. This alteration can be made as follows:

(338.) To keep the ⊕ section and all the other sections at the same places as before, the exponent n of the line of sections remains the same $= 2.6385$, whence the area of the ⊕ section is $= \dfrac{n+1.D}{n\,l} = 1027.20$. Let h be a tenth of an inch longer, then h is $= 18.213$, hence B is $= 56.4$; the breadth has thus obtained an increase of 0.13 foot.

(339.) The lowering of the metacentre, which is caused by the increase of the displacement, is counterbalanced by the small increase of the breadth; thus the situation of the metacentre is not changed. This brief account of the notions of the celebrated Chap-

man, shows at once the superiority of the plans of Seppings.

On the Heads and Sterns of Vessels.

Heads and sterns of vessels.

(340.) In the earliest times, the favourite emblem of each particular nation rarely failed to appear when any opportunity presented itself for its introduction. Accordingly we find the Owl constantly appeared on the Athenian prow, and the Cock, the emblem of vigilance, on those of the Phœnician Colonies; and that much importance was attached to the formation and decoration of this part of a vessel, may be gathered from the abundant illustrations afforded by ancient coins. Many of the designs remaining to us of these ancient prows, prove their contrivers to have been anxious, not only for the employment of such improvements and inventions as had mere utility, or the annoyance of enemies to recommend them, but many were designed for no other purpose than magnificence and splendour.

Decorations of stern surpassed those of the head.

(341.) The decorations of the stern, or poop, however, very much surpassed those of the head; and to it were attached, at the extremity of a staff or upright pole, those floating streamers of various colours, which have descended even to our present times. The cumbrous and expensive ornaments, therefore, which continued to decorate ships at the commencement of the XVIIIth Century, may find an apology in the customs that prevailed two thousand years ago.

Change in the figure-head of our ships in 1796.

(342.) In 1796, the Admiralty, at the head of which was Earl Spencer, directed that the ponderous heads which disfigured our ships should no longer be continued, and that the galleries and carved work should be removed from their sterns. This was a great step towards that simplicity so much to be desired in every mechanical construction; but it was not till 1811, that Seppings was enabled to bring the simple circular bow now employed into use; nor till 1816 that he proposed that the same system should be adopted in the stern.

Seppings's bow and stern.

(343.) The alteration of the bow was generally regarded as a salutary improvement; but the change of the stern met with the most violent opposition, founded chiefly on the erroneous idea that our seamen were likely to run from the enemy. Other notions connected with beauty and deformity were urged with singular pertinacity; but the unanswerable arguments founded on experimental evidence, satisfactorily proved to every unprejudiced mind, that the introduction of this change of form, added considerably to the strength of the ship, considered as a mechanical framework; that the safety of the crew was very much increased both from the effects of a sea striking the stern, and from shot fired by an enemy; and, moreover, that the additional means afforded for attack and defence were very much increased.

Comparison of means of attack by round and square sterns.

Some evidence of the mechanical strength may be gathered from a simple comparison of the forms in fig. 12 and 13; and of the augmented means of attack or defence from fig. 14 and 15. The objections made as to form have been entirely obviated by the model proposed by Mr. Roberts; and it is satisfactory to find, that an improvement, too long regarded with indifference or hostility, is now likely to be adopted as a permanent improvement in the British Navy.

On Timber for the Navy.

Timber for the Navy.

(344.) When we survey the framework only of a single ship of war, the thought immediately occurs to the mind how many acres of forest trees must have been felled in order to furnish suitable timber for its formation; and when we further reflect on the slow growth of the oak, and on the comparatively limited surface of territory in our own Country covered by this noble tree, together with the enormous consumption necessary for the formation and maintenance of our Navy, and all the hosts of our commercial fleets, with all the varied requirements of the useful Arts, it cannot but become an anxious subject for consideration, how these multiplied demands can in perpetuity be supplied.

Importance of cultivating timber pointed out by Evelyn.

(345.) The public attention was first aroused to the importance of cultivating timber, by the immortal *Sylva* of Evelyn. "Many causes," says Mr. Upcott in his Preface to Evelyn's *Miscellaneous Writings*, "had operated to the diminution of our woods and forests.* Men were not planters but destroyers of wood, without thought of the future; but the Civil wars gave a final blow to the work of havock: the aged oaks, like the old families which owned them, were, by these enemies of all that was elegant and venerable, doomed to destruction: feeling their tenure insecure, and professing themselves against root and branch, either to be reimbursed their holy purchases, or for some other sordid respect, they were tempted not only to fell and cut down, but utterly extirpate, demolish, and raze, all those many goodly woods and forests, which our more prudent ancestors left standing for the service of their Country."

Evelyn's *Sylva* first Work printed by order of the Royal Society.

The Work of Evelyn was the first book printed by order of the Royal Society. "It sounded the trumpet of alarm to the Nation on the condition of the woods and forests, and awakened the landholders to a sense of their own and their Country's interests. He lived to know that many millions of forest trees had been propagated and planted at his instigation." And who can estimate the benefits he conferred? who can say, after reflecting on the Naval conflicts this Country has had to pass through since the time of that great man, how large a portion of our Naval glory is to be attributed to him?†

Laws enacted for making enclosures.

(346.) During the reigns of Charles II. and William III. laws were enacted for making enclosures in the Forest of Dean in Gloucestershire, and the New Forest in Hampshire; and had those wise and prudent measures been continued to be acted on with all

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* From the records of the Royal Forests, it appears that in 1608 a survey was made of six of them. There was then found fit for Naval purposes 234,229 trees, and of decayed trees the enormous number of 263,145.

† Evelyn laboured to the end of his long life in giving to his *Sylva* all the perfection in his power; and at a late period we find him thus encouraging the planter with the promise of longevity: "It is observed that planters are often blessed with health and old age. The days of a tree are the days of my people, says the prophet Isaiah. *Hæc scripsi octogenarius*, and shall if God protract my years, and continue my health, be continually planting, till it shall please him to transplant me into those glorious regions above, planted with perennial groves and trees bearing immortal fruit." "While Britain," says Mr. D'Israeli, "retains her awful situation among the nations of Europe, the *Sylva* of Evelyn will endure with her triumphant oaks. It was an author in his studious retreat, who, casting a prophetic eye on the Age we live in, secured the late victories of our Naval sovereignty. Inquire at the Admiralty how the fleets of Nelson have been constructed, and they can tell you that it was with the oaks which the genius of Evelyn had planted."

Evelyn says, "So precious was the esteem of the oak, that of old there was an express law among the Twelve Tables concerning the very gathering of the acorns, though they should be found fallen in another man's ground."

the energy our insular situation ought to have commanded, much of that anxiety which the enormous consumption of the last war produced, could not have occurred. The first great advance in the price of oak timber took place soon after the Restoration.

In 1771 a Committee of the House of Commons appointed respecting oak timber.

(347.) In 1771 a Committee of the House of Commons was appointed to inquire into the state of oak timber throughout the Kingdom; but singularly enough, from a difference of opinion, or defect of evidence, or a wish to avoid giving alarm, the Committee prayed to have that part of its order discharged which required them to report their opinion. In the following year, the Legislature interfered to prevent the East India Company from building ships in England until the amount of their tonnage should be reduced to 45,000 tons, affording by inference what that opinion was. In 1783, when the six Royal Forests alluded to in a preceding note were surveyed, it was found that the trees fit for Naval purposes amounted only to 50,455, and decayed trees to 35,554, exhibiting a decrease from 1608 of nearly four-fifths. There is, also, reason for believing that a corresponding diminution had taken place in all the Royal Forests. The quantity of English oak timber consumed for the Navy, from October 1760 to December 1788, amounted to 1,276,362 loads.

In 1788 Committee re-appointed to examine into the alarming state of our forests.

(348.) In 1788 the consideration of the subject was renewed with more energy, and a better prospect of success. The state of our woods and forests had begun to excite the most serious inquiry in Parliament. The immense expenditure of wood, particularly of that technically called compass timber, filled all thinking men with a well-grounded apprehension that our supply might fall very far short of the demand; and this alarm in all probability would have been realized, but for the happy introduction of iron, which during the War of the French Revolution had in so many ways been employed with advantage in the practical Arts. It seems to have been admitted on all hands, that prior to the period last adverted to, there had been a most extravagant waste of oak timber, a waste not only injurious to the financial resources of the Country, but also to the production of the article itself. Trees were felled in a premature state without consideration, nor was any care taken that their places should be supplied by a younger stock.* Men thought only of the present, anxious no doubt for their Country's good, but without that portion of wholesome care, which in every condition of life is the main spring of all transcendent and long-continued exertions. The amount of private shipping had increased during the sanguinary conflict here adverted to, from 1,300,000 tons to 2,500,000; that of the East India Company during the same period from 79,000 tons to 115,000; and the Navy, rising in gigantic power with all our difficulties, augmenting from 400,000 to 800,000 tons. And if in addition to all this we reflect, how greatly the manufacturing energies of the Country had been quickened; how on the right hand and on the left, in districts hitherto unblest by the presence of the Mechanical Arts, mills and enormous erections of machinery were in abundance created; docks, dock gates, slips, sluices, and piers, boats, barges, and bridges, in all our harbours; the operations of mining, extensive coal works; the pursuits of agriculture; the construction of innumerable barracks; the demands of the ordnance;—in all these and many more, oak timber being required in an abundance unthought of by the most sanguine speculator of a former Age;—when upwards of 100 sail of the line were in active commission, 160 frigates, 200 sloops, besides bombs, gun-brigs, cutters, schooners, &c., together with an immense fleet in ordinary, performing various offices: no wonder when all these combined causes were in full activity and play, and the price of the article, the sure criterion of the stock in hand, began to augment with the most rapid strides, that the public attention was aroused, and that Parliament in all right energy and power took up the question. It was calculated about this time that the whole consumption of oak for the Royal Navy, the East India Company, the Merchant Service, the internal demands for buildings of different kinds, canals, machinery, docks, &c. amounted to 4,015,000 tons.

Great preparations made in 1808 to meet the coming evil.

(349.) Accordingly in 1808, when the last embers of the hope of Peace had well nigh expired, and when men began to fear that a contest already unexampled in its fury and expense might yet be indefinitely prolonged, the Commissioners of Woods and Forests began to make active arrangements to meet the coming evil. In 1812 they made their first Report, and afforded some data by which a proper notion might be formed of our condition. Taking the tonnage of the Navy, said they, in 1806, at 776,087 tons, it would require, at the rate of one load and a half to a ton, the enormous quantity of 1,164,085 loads to build such a Navy; and supposing the average

Loads of timber necessary to build such a Navy as ours.

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* Evelyn in his Letter to Mr. Aubrey remarked, that where goodly oaks grew and were cut down by his grandfather a hundred years before, beech only was then to be seen. He saw this to be an evil, and how has the evil multiplied and spread since his time! Arthur Young was of opinion, that in the Counties best adapted for the growth of oak, Kent, Sussex, &c. not one acre has been planted for fifty acres of wood-land that has been grubbed up. From the time of the *Domesday-book* down to 1792 there was a gradual diminution of wood-land. A competent person remarked in 1813, that if we except the Royal Forests, and perhaps the estates of some half a dozen great landholders, such as the Dukes of Devonshire, Norfolk, Portland, Newcastle, &c., it may be doubted whether any thing like a regular plantation of oak timber has taken place for the sixty years preceding.

It has been remarked, that the quantity of acorns which the oak bears, has made many people suppose, that Nature has taken care to renew a supply for us; and that of this vast quantity of seed, which annually falls, there will always be a superabundant supply of young trees, growing up in the place of the old ones; but experience proves that this is by no means the case. The greater number of these fallen acorns is devoured by many different animals, for whose nourishment Nature has provided that abundance of them; and of those which escape this fate, we are to consider how few can come to perfection, from the natural accidents to which they are unavoidably exposed. Acorns fall on a covered ground, where dead leaves and decayed branches of trees usually prevent their touching the earth; or if circumstances are more favourable, and they are enabled to shoot, it is merely from the surface, where they are, from the slowness of their growth, liable, while very tender, to the influences of frost; and added to this, it is very difficult for such tender plants as the young seedlings of these to find room for growth or nourishment among the roots of other trees spreading every way. The continual shade and want of free air also must render them very weakly and irregular in their growth, even supposing they are able to surmount all other difficulties.

It is, indeed, certain, that oaks are frequently met with among the underwood of forests, but this is only the case in spots where there has been a vacancy or opening; and that usually, where there are not, nor have at any time been oaks in the neighbourhood of the spot. Those trees which grow at a distance, result most likely from the accidental acorns brought thither by birds. This is an instance familiarly verified, by observing, that there are frequently little bushes near woods, which, though of white-thorn, or other trees, are usually surrounded and ornamented with young oaks. Jays and like carnivorous birds are the real authors of these crops.

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duration of a ship to be fourteen years, and there are many strong reasons for believing that this is too highly rated, an annual amount of 83,149 loads would be required, exclusive of repairs, which they estimate at 27,000 loads, making in the whole about 110,000 loads, towards which, however, they thought the bravery of British seamen might yearly afford 21,341 loads in the shape of prizes;* and from other sources than British oak 28,659 loads might be drawn, leaving a demand of 60,000 loads annually for the oak necessary for supporting in its then unexampled magnitude, the whole British Navy, including ships of war of all sorts, which may be regarded as equivalent to twenty 74-gun ships, containing one with another as constructed at that time, about 2000 tons, or 3000 loads of timber.

Annual demand in loads on this hypothesis.

Number of trees necessary for a ship of the line.

(350.) Now it has been estimated on an average, that of such oak trees as are necessary for constructing ships of the line, forty cover an acre of ground. Hence 50 acres of land, stocked at this rate with the finest trees, would be necessary for the construction of such a ship; and, consequently, 1000 acres for the twenty ships assumed as the annual consumption. Now, the oak, slow of growth, requires at least a century to bring it to maturity; and hence 100,000 acres would be required to keep up a successive supply for maintaining a navy of 700,000 or 800,000 tons. The Commissioners hence observed, that as there were 20,000,000 of acres of waste land in the Kingdom, a two-hundredth part set aside for planting, would at once furnish the whole quantity wanted for the Navy.

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Objections to this computation.

(351.) This computation, it has been remarked, is very considerably overrated. It proceeded on one great and melancholy hypothesis,—perpetual war, and an amount of tonnage more than double its present actual amount. Added to which it was also questioned, whether fourteen years was not too low an estimate for the average duration of ships; but after what we have seen of the ravages of dry rot, we prefer calculating on the safe side. Assuming, however, with the author of a statement of apparently good authority, made in the midst of the War, the actual tonnage kept in commission to be 400,000 tons, and the average duration of a ship of war to be 12½ years, there would be required an annual supply of tonnage to preserve the Navy in this state, amounting to 32,000 tons, or 48,000 loads of timber. According to the hypothesis before alluded to of the consumption for a 74-gun ship, these 48,000 loads would build 8 sail of the line and 16 frigates. Allowing one-fourth more for casualties, the annual consumption would be 60,000 loads, or 40,000 full-grown trees, of which thirty-five will stand on an acre. The quantity of timber, therefore, necessary for a 74-gun ship will occupy 57 acres of land,† and the annual demand will be the produce of 1140 acres. Allowing, also, only 90 years for the oak to arrive at perfection, there ought now to be standing 120,600 acres of oak plantation, and an annual felling and planting, in perpetual rotation of 1140 acres, to meet the consumption of the Navy alone. Large as this may seem, it is little more than 21 acres for each County in England and Wales; which is not equal to the belt surrounding the park and pleasure-grounds of many estates.*

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Further remarks on the computation.

(352.) This calculation proceeds on the supposition that every acre of the great surface of land referred to, is covered with timber fit for the purposes of ship-building; and that the greatest possible care is taken to nurse the plantations up to that standard. It may, however, be reasonably doubted, if we take the average condition of the Country into consideration, whether more than one-tenth of that number could be found on a single acre. Adopting also the ratio fixed on by some able writers, that the quantity of oak timber consumed in the Navy is only a tenth part of the whole consumption of the Country, it is evident that upwards of 12,000,000 of acres would be necessary to satisfy the whole demand. We have no means of answering the question whether such a quantity exists or not; but we know, that long before the conclusion of the War, a scarcity began to be felt, especially of the larger kind of timber fit for ships of the line.

Our duty at this time to encourage in every way the growth of oak.

(353.) This Essay is, however, written under the favourable circumstances of Peace, and when the difficulties we have passed through exist in our minds only as important Historical facts. It is our duty in a season of such a kind to look around, to husband our resources, and so to augment them as to enable us to enter with confidence into those untried scenes which may yet be in store for us. Not only is it our duty to encourage the growth of oaks, but also to keep our attention steadily directed to the timber to be found in our Colonial possessions. It has been truly observed, that the superior quality and abundance of the teak timber of India, and the Naval establishments in that Country, are available resources for keeping up our Naval strength, far too important to be in any way neglected.

* The splendid Naval achievements of the late War prove that this was not an improper supposition. During that War, England seemed to have swept from the Ocean the fleets of her enemies. There were captured or destroyed during that arduous conflict 156 sail of the line, 382 large frigates, and 662 corvettes, in all 2506 sail of vessels of war. It appears, also, that on the 30th September, 1811, there were prize ships, admitted to registry, and added to the commercial Navy of Great Britain, no less than 4023 ships, measuring 536,240 tons.

† On the hypothesis of 35 trees growing on a single acre, it will require for the building of a 120-gun ship, according to the present mode of construction, 168 acres of land; of an 80-gun ship 124 acres; of a 74-gun ship 103 acres; of a 52-gun frigate 68 acres; of a 46-gun frigate 51⅓ acres; of a 28-gun ship 27⅓ acres; of an 18-gun corvette 18 acres; of an 18-gun brig 13½ acres; of a 10-gun brig 9⅔ acres; of a schooner 7 acres, and of a cutter 5¼ acres. For one ship of each of these classes, 595 acres of land would be necessary, stocked according to the hypothesis adverted to.

* At the time Lord Glenbervie was Surveyor General of the Woods, &c., he reckoned in his first Report that 60,000 acres might be obtained from the several Royal Forests; and that the remaining 40,000 might probably be found among the forest lands in the Duchy of Lancaster, from Needwood forest, 3000 acres of which were appropriated to the Crown, from allotments to the Crown on the division of wastes and commons, by purchase, or otherwise, of lands locally situated within the different Royal Forests occupied by individuals either by legal title or by encroachments, by purchase of wood-lands from private owners, and by purchasing out, or refusing the renewal of, Crown leases of land containing oak coppices or land fit for the growth of oak. To which might be added a reservation in every Enclosure Bill of a certain proportion to be set apart for the express purpose of planting oaks, besides an obligatory clause to plant oaks in the fences at limited distances. His Lordship also thought that the 100,000 acres should be enclosed and planted at the rate of about 4000 acres annually, which would complete the whole in about 25 years. The present and intermediate supply will be obtained from timber now ready for felling, and in its different stages in the Royal Forests, on private estates, from thinnings of the new plantations for inferior purposes, by importations of foreign oak, and by the use of other kinds of timber. At the time this Report was drawn up 35,000 acres had already been appropriated in this way; and since that time our energies have not been slackened.

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The supply which the forests of India yield, if not made use of in ship-building, must, like many other resources of that splendid region, be entirely lost to the nation.

Teak.

(354.) The teak forests are in the Ghauts of the interior, both to the Northward and Southward of Bombay, but chiefly in the latter direction. Lord Wellesley was the first, in consequence of a communication from Lord Melville, to cause the teak forests of Western India to be examined, and measures were adopted for procuring a regular supply from them. The East India Company purchased various wood-lands, and the supply seems now inexhaustible.

Its quality.

(355.) The quality of teak is in many respects preferable to that of oak for ship-building. Alternate exposure to a vertical sun, and to the drenching rain of the wet monsoons, which would rend in pieces European oak, produces no injurious effects upon teak. Many of the upright timbers for securing the stays in the Old Docks at Bombay have stood more than forty years with paint or tar, and in 1812 were still as perfect as when first erected. A piece of the same wood also, taken out of a gate of one of Tippoo's forts in Canara, which had been exposed to every change of weather for more than half a century, when brought to Bombay was ascertained to be unimpaired, with nails, which had secured it, quite free from corrosion or rust, and as sound as when first driven. The Turkish flag ship at Bussorah was built by Nadir Shah, and after seventy years, when examined at Bombay, was found perfectly sound. The Hercules of 485 tons, built at the same place in 1763, when captured by the French in 1783, was entire in every part; and the Milford of 679 tons, after constant employment between China and Europe for 24 years, was examined, and no timber found which required shifting. Her teak main mast continued in her twenty-one years, when, being partially sprung, it was converted into a main mast for a smaller vessel. Teak possesses the valuable property of preserving iron, while oak destroys it. A piece of teak plank, which had been bolted to the side of the Chiffone frigate, was removed at the end of eight years. That part of the iron bolt buried in the teak was found perfectly good, whereas that which had been in the oak was totally corroded.

Larch.

(356.) Much has been said in favour of larch for the purposes of ship-building. So fully was the Empress Catherine impressed with its value, that the exportation of it from Russia was at one time prohibited. The rapidity of its growth is so great, that it has been found to double in diameter that of the oak in the same given time, and hence to produce four times the quantity of timber. From several experiments it has been found not inferior in strength, toughness, and elasticity to oak. The Dukes of Athol and Montrose, Lord Fife, and several other great landholders in Scotland, have made very extensive plantations of this tree and the Scotch fir, which are rapidly rising into magnificent forests, and will enable us in future years to diminish the consumption of our native oak.

Where timber fit for ship-building may be obtained.

(357.) Trinidad contains about a million and a half of acres, two-thirds of which, at least, are covered with wood, and wholly the property of the Crown. The Spanish peons, or labourers, are extremely dexterous at felling and squaring timber, and work at a cheap rate. In Canada, Nova Scotia, and New Brunswick, also, we possess immense forests abounding with oak for ship-building. With all these Colonial resources, added to our own domestic supplies, and the great attention now paid to the rearing of the oak in our Royal Forests, we have little fear of obtaining an abundant quantity whenever the warlike energies of the nation may be again called into exercise.

(358.) In the Mediterranean Islands, in the Morea, in Albania, Dalmatia, and Croatia, the finest oak timber, in point of size and shape, is most abundant.

Report of French Commission on timber.

(359.) In the *Annales Maritimes* for June 1828 is a Report of a Commission charged by the French Government with the examination of woods imported from Africa. Of the *cail cedra* it was said, that though less flexible, it is tougher than oak, and being as strong, without being heavier, may be quite as advantageously employed in Naval construction. The *gonakier*, almost as flexible as oak, and at the same time possessing one half more strength and toughness, is better calculated for the frames of ships. The *dethard*, of equal strength with oak, is more flexible, but has not so much elasticity. It appears very well adapted for planking, and as a substitute for compass timber. The *turtosa* has rather less flexibility than oak, but is superior to it in every other respect.

Timber suitable for mast-making.

(360.) For many purposes, if timber have strength and durability, it possesses every necessary quality; but there are some applications of wood in which other qualities are necessary, such as flexibility, elasticity, and lightness. This is particularly the case in mast-making, a branch of ship-building on which the most important considerations depend. If a mast possesses so great a degree of rigidity as not to yield to the sudden shocks to which it is subject, it must soon become fractured; and if its resilience when bent be not sufficient to cause it to recover its true position, it is rendered weaker at every impulse.

Fir and pine.

(361.) The timber commonly used for masts is fir and pine, distinguished according to the character of their leaves and cones. By mast-makers it is distinguished by the name of the place from which it is imported, as the Norway and Riga firs, Canada red and white pines, &c. According to Mr. Fincham, the timber that possesses in the greatest degree the qualities best suited for masting, is the *pinus silvestris Genevensis vulgaris*, abounding in the vast forests of Russia, Norway, and Poland. The most esteemed is from the Ukraine and Livonia, and is brought down the Dwina. It is commonly called Riga from the port from which it is shipped, in the same way as the Adriatic fir derives its name from being shipped in the Adriatic. The different firs and pines, besides those of the North, used for masting the Royal Navy of Great Britain, and likewise to a great extent her commercial Navy, are principally those from Canada, with some from Nova Scotia, and a few from Scotland. The timber from Canada consists chiefly of the *pinus strobus*, or what is commonly called the Weymouth, or white masting pine; and the white, red, and black spruce, *pinus Canadensis*. The Scotch fir, *pinus silvestris*, is common in the Highlands of Scotland, as well as in Norway, Denmark, and Sweden.

Remarks on varieties.

Further remarks on varieties and uses of Pine. Poon.

(362.) Standing masts are generally made of yellow pine, and topmasts of red. The white, red, and black spruce are but little employed, excepting for small spars. The Adriatic fir is frequently used for the masts of cutters and other small vessels, but its qualities are not very good. Timber denominated Poon has been partially used for masting ships built in India; and the Cowrie brought from New Zealand has been employed

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for small standing masts, and for topmasts even for a first-rate. This latter possesses many of the most esteemed qualities for masting.

French obtain supplies from Corsica, Pyrenees, &c.

(363.) The French, according to Forfait and others, have received considerable supplies from Corsica, from the Pyrenees, from Catalonia, Savoy, from the neighbourhood of Mont Blanc, Puy de Dome, and Cantal. These firs, however, contain but little resinous matter. The heart is porous and the grain close, and their flexibility is but very trifling. They soon become dry and break under very slight strains.

Turks, from shores of Black Sea.

(364.) The Turks obtain excellent firs from the shores of the Black Sea. They are commonly of the species denominated *pinus pinea*, and *pinus laricis*. They are but little inferior to the trees of the North.

Great practical skill requisite to judge of wood.

(365.) It requires great practical skill and experience to judge of the qualities of any kind of wood. In the selection of firs for masting, the climate, aspect, and soil in which they grow must be attentively considered. To judge of the qualities of trees while standing, is the duty of those employed in the forests; while the mast-maker makes his selection from the trees when felled, and judges of them as timber. The most desirable firs have a fine and close grain, with the ligneous layers closely blended together, and their annual concentric circles finely and firmly connected, decreasing gradually from the heart to the sap. The nearer these layers approach to circles or ellipses, the less likely is the timber to be defective. They are, generally, highly charged with resin, giving strength and elasticity, preserving the timber from insects, and preventing fermentation and decay. The colour should be of a clear or bright yellow, with a reddish cast alternately. The smell of Riga and other firs of this quality, should be strongly resinous, especially when they are exposed to the sun, or their shavings are rubbed between the fingers. In cases where the layers are open, with pale red tints near the heart, and white spots intermixed; or where they are of a dark red colour with the resinous particles of a blackish colour, the timber is in a state of decay. When firs are cut transversely, and not of an uniform colour, but interspersed with veins, and the smell is entirely gone or become fetid, they may be considered as past their prime, and approaching a state of decay. In some yellow and red pines, the degree of unsoundness is indicated by the offensiveness of the smell, and alternate layers of a foxy-brown, or red colour, will break out before the sharpest plane on being wrought.

What are the most desirable firs.

How the experienced mast-maker judges.

(366.) The experienced mast-maker, says Mr. Fincham, forms his opinion of the quality of a stick, not only from the colour, smell, and appearance of the grain, but also by its working; for as a stick is more or less fragile, the greater or less difficulty he has in separating its parts, as he chops them off. If the timber is good, its parts, on being separated, appear stringy, and oppose a strong adhesion, and the shavings from the plane will bear to be twisted two or three times round the fingers; whereas, if the stick be of a bad quality, or in a state of decay, and has lost its resinous qualities, the chips and shavings come off short and brittle, and with much greater ease.

Further remarks on quality.

(367.) Those kinds of timber that have but little or no resin, and whose colour is of a whitish or light brown cast, and are of rather a coarse grain, as the Adriatic, Norway, &c., will, as they become dry, though they maintain their strength and resilience for a considerable time, be so rigid that they will always be subject to break, by any sudden impulse, without warning, especially if they are kept in dry stores for a long time.

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(368.) The Riga and other timbers containing a proper quantity of resin, and the red pine, from the fineness and closeness of its grain, and the adhesiveness of its fibre, not only maintain their resilience, but their strength and flexibility much longer, even to a dry state.

Cowrie.

(369.) The Cowrie possesses advantages over most other timber, from the firmness of its grain, and the uniformity of its texture. The experiments which have been made on this timber, compared with the Riga, Dantzic, and other esteemed firs, justify the conclusion that it possesses equally good qualities with these timbers, for all the purposes for which they are generally used. When exposed to the weather, it appears less liable to shrink, and stands equally well with them. The Cowrie spars that have been brought to England, appear but a little beyond saplings, since many of the full grown trees are said to exceed 30 feet in girth, and to continue the full size to nearly 60 feet from the ground. Their common diameter is from three to six feet, and their length frequently from 90 to 100 feet clear of branches.

Valuable information to be derived from practical men.

(370.) These are some of the results which long practical experience affords, and are the only solid groundworks of improvement in the Mechanical Arts. In the various applications of timber, and in none more so than in mast-making, accurate experience is of the greatest importance. The Philosopher, as he passes through a workshop, learns to value men who, at every step, may afford him some useful information; something probably which had been handed down by tradition from one generation of workmen to another, but with which he is not acquainted. And that knowledge of this kind is indispensable, if he wishes to gain an accurate acquaintance with the Arts of life, will be readily conceded by him whose mind has been properly disciplined and trained; who regards all the practical Arts as helpmates to Science; and as the only certain foundations for the very best departments of our knowledge.

Dry Rot, and other Sources of Decay.

Dry rot, &c.

(371.) One of the most formidable evils the Navy of England has had to contend with is the dry rot; a subtle enemy, more terrible than the bullets of the greatest cannon, decomposing the fibres of timber, depriving the largest trees of all their strength, and in a few years reducing the whole fabric of the noblest vessel to a mass of dry dust.

Great developement of it in our own times.

(372.) It has been reserved for our days to see this destructive agent develope itself with gigantic power, attacking many of our modern built houses, and sapping with irresistible energy our finest built ships. The inquiring mind naturally asks, how vessels built half a century ago are more durable than these constructed at the present time; to what circumstance it is to be attributed that the beautiful roof of Westminster Hall is as sound and as perfect as on the day it was built; why the mansions and Baronial halls of the olden time seem destined to survive the modern built villa; why some of our oldest ships should exhibit fewer elements of decay than the vessels on which all the resources of Modern Art have been bestowed?

Masts.

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Dry rot coeval with timber trees.

Public attention first directed to it in 1810.

(373.) There can be no doubt that this disease, whatever it be,—for its nature and cure seem almost equally unknown, must have been coeval with timber trees themselves, though not known by its present name, or exhibiting so formidable examples of its power, until about the middle of the last Century.* About the year 1810,† however, the public attention was first seriously awakened to its importance, in consequence of the Queen Charlotte, a noble first-rate ship of war, having been launched at Deptford, sent round to Plymouth under jury masts in 1811, found too rotten to be seaworthy, and in the following year undergoing a repair, amounting, it is said, to £30,000. All her upper works were infected with dry rot; the ends of her beams, carlings, and ledges, and the joinings of her planks being covered with a mouldy, fibrous, and reticulated crust, the portions of her timbers so covered being altogether rotten. It would be endless to enumerate the abundant speculations to which this remarkable occurrence gave birth. Theories of its origin, remedies for its cure were offered on all sides; and while the severest critic could not but applaud the zeal and patriotic spirit which animated their authors, the melancholy conviction was forced on his attention, that neither for one nor the other was any sound or rational opinion offered.

Numerous theories and remedies consequent thereon.

(374.) Among other objects of discussion was the inquiry whether the common rot and the dry rot were the same; and it was soon perceived that the two were essentially different,—different in their origin, and very different in their modes of operation. The common rot, it was remarked, is a gradual decay of the fibre of the wood, more or less accelerated by the uncertain action of wind, heat, and moisture on its surface; its progress internally being greatest when the timber is constantly exposed to alternations of wet and drought, as exemplified in the rapid decay of that part of a post which is close to the surface of the earth, while all above and below is perfectly sound; and least, when constantly soaked in water, or kept constantly dry, exposed to a free current of air, or excluded entirely from it.

Common rot and dry rot.

Nature of the common rot.

(375.) The dry rot, on the contrary, commences its ravages internally, and is but little affected by any external circumstance, excepting that of heat. Its external characters are differently described by different observers. By some a fine mouldy coating has been observed to spread over the wood, of a brownish-yellow or dirty white, which soon begins to resemble in form and structure some of the beautiful ramified algæ or seaweeds. This in a little time becomes more compact, the interstices being so completely filled up as to give to the whole the appearance of leather. By others it has been represented as fibres running over the surface in endless ramifications, resembling the nervous fibres of leaves; the interstices being filled with a spongy-like substance assuming the character of that order of Cryptogamous plants distinguished by the name of *fungus*.* According to Mr. Wade, the wood at first swells; after some time it changes its colour, and then emits gases which have a mouldy or musty smell. In more advanced stages, the wood cracks transversely, and in its latter stages becomes pulverulent, forming vegetable earth; and, generally, in some of these stages of decay, the different species of fungus are found to vegetate on the mass.

Nature of dry rot.

Its external characters.

Different descriptions of it.

(376.) These appearances do not, however, invariably happen, the surface of the diseased timber sometimes remaining unchanged, while the process of rotting is going on within; and however sound the surface may be, the whole of the exterior fibres become decomposed, presenting a mass of dust inclosed within a thin external shell. No charring of the surface, no external application of paint, tar, or varnish, will stop its ravages where the seeds of the dry rot exist in a situation favourable for their growth, though the external character of mouldiness may by such means be prevented from appearing on the surface.

Diversity in its appearance.

(377.) This terribly destructive agent was discovered in all our harbours, and sapping the vitals of our ships more or less, wherever they were found on the sea. From the best information that can be gathered, it appears, that to the rapid construction of our ships during the late War, may be attributed their very extraordinary decay. When Lord Spencer quitted the Admiralty in 1801, it has been generally supposed that he left an efficient fleet, but this was by no means the case. It was numerous indeed, but many of the ships were nearly worn out. Lord St. Vincent, his successor, determined to build no more ships in merchants' yards, and the King's yards were almost wholly occupied in patching up those actually in commission, and those brought forward from the ordinary. In 1804, when Lord Melville succeeded to the Admiralty, the Navy was wholly inadequate to the situation of the Country; scarcely one of the ships in commission having more than three years to run, most of them but two, and many only one; a few, and but a few, new ones were slowly coming forward in the King's yards, and none in the merchants' yards. Thus circumstanced, recourse was had to private builders, who were wholly unprepared with materials. Contracts, however, were entered into at advanced prices, the axe was set to work, and trees which were one year growing in the forest, were in the next floating on the ocean; and up to the termination of the War, so closely did the demand press upon the supply, that few, if any, ships were built in the Royal yards with

Rapid construction of ships the cause of their decay

Lord St. Vincent determined to build no more ships in merchants' yards.

Dangerous state of the Navy in 1804.

Lord Melville compelled to have recourse to private builders.

* Mr. Knowles, in his inquiry into the means which have been taken to preserve the Navy, cites the 14th Chapter of *Leviticus*, in which dry rot is accurately described under the name of "leprosy in houses," and the same remedies directed to be applied, which have been practised with success in our own time. That dry rot also existed in the latter part of the XVIIth Century may be inferred from Mr. Pepys, who gathered toad stools in their holds "as big as his fists."

† The term "dry rot" was not inserted in any official document earlier than 1808.

* The Author of this Essay, early in life, had a book-case with close doors in its lower part, in a study on the ground-floor of a new house. Into this lower compartment of the book-case, he had put a number of books he was not in the habit of using, together with many MSS. The doors were not opened for many months, but one day finding it necessary to refer to some Work, he opened the doors, and to his great amazement saw every opening filled with the most beautiful varieties of fungus. On examining the books, some of them crumbled beneath the slightest touch; and between all their leaves, the finest layers of a very thin leather-like substance were found. This substance had removed all traces of writing from many of the MSS., and many fell into the finest powder. The lower part of the book case was completely rotten, and on examining the wood-work of the house, such as the lower partitions, floors, stairs, &c., nearly the whole was found completely decayed. In a short time the staircase must have been broken down even by a little child treading on it, so active had been the work of destruction. He lost several rare and valuable Works, and some important MSS. on this occasion.

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well-seasoned timber. Hence the probable origin of an evil, which at one time filled the stoutest hearts with dismay, and reparation of the ravages of which has cost the Country millions.

Scarcity of oak.

(378.) The scarcity of our own noble oak contributed greatly to accelerate this fearful state of things. Its employment in the same vessel in a seasoned and unseasoned state, and its mixture with different kinds of foreign timber, led to the most disastrous results. The Queen Charlotte before adverted to was nearly seven years in building. Of the timber employed in her construction, some was seasoned and some quite green. Part of it consisted of Canada oak, and part of pitch pine, both peculiarly susceptible of dry rot. Her timbers were covered with as many species of the *boletus* as there were different kinds of wood employed in her construction. During our long protracted War we had line of battle ships constructed in the Royal Dockyards entirely of oak from Holstein, and frigates in the same establishments altogether of fir imported from the Baltic. In the river Thames, also, we had gun-brigs built of this latter material, and numerous frigates of the red pine, pitch pine, and yellow pine of America. At Bombay, Calcutta, and Cochin, ships of the line and vessels of other classes were formed wholly from teak. At Prince of Wales's Island, frigates were constructed of the different sorts of wood abounding in that Island; at Halifax, ships of birch, red pine, and oak; at Bermuda numerous vessels entirely of cedar. The Athol, also, was built in England entirely of larch. From Sierra Leone, timber was imported for ship-building. Of these varieties, teak is the most durable, and the red pine of America the least so. Frigates framed from this latter wood seldom lasted longer than four or five years.

Mixing different kinds of wood injurious. Seasoned with unseasoned.

Varieties of wood employed in our Dockyards during the War.

Examples of bad building.

(379.) As practically authentic examples of the evils resulting from the careless employment of unseasoned timber,—of bad workmanship unchecked by vigilant superintending officers,—as examples, we fear we may say, of those tremendous frauds, which to a greater or less degree prevailed in most of our public departments at this time, we select from a host that might be adduced the following. The Rodney, line of battle ship, built in the private yard of Barnard, was launched in 1809. She had scarcely put to sea, when, owing to the unseasoned state of her timber, all her planks became loose, and it was necessary to bring her home from the Mediterranean in 1812 to be paid off.* The three King's master-shipwrights, who examined her, reported that they found a bolt in the chock of a beam not passing through the ship's side, and that a hole bored for a bolt had only putty put into it. The Dublin, built in Brent's yard, was launched in February 1812, put in commission in the following August, sent upon a cruise towards Madeira and the Western Islands in December, from which she returned to Plymouth in February 1813, in so dreadful a state, that she was ordered to be paid off. The officers of the Plymouth yard stated in their report of this ship, that "her defects exceeded any thing they had ever witnessed in a new ship."

Disgraceful workmanship.

Enormous cost of repairs.

(380.) An idea of the enormous cost of repairs may be gathered from the following brief Table, part only of a catalogue which fills the mind with the deepest indignation:

	When Built.	First Cost.	Time of Service before being docked. Yrs.	Mos.	Cost of Repairs.	When paid off.
Superb..	1798	£38,647	2	6	£47,283	1809
Ajax....	1798	39,039	0	5	26,683	1802
Achille .	1798	38,450	1	5	25,646	1802
Spencer.	1800	36,249	2	9	43,748	1802

In two cases out of the four the repairs considerably exceeded the original costs of the vessels. The surveying officer who superintended the building of the Ajax,

* The resident overseer who in such cases superintended the building of a ship, was what was then denominated a quarterman, one degree above a common carpenter, at a salary from £160 to £180 a year. This person was appointed to overlook and to check the work of a Body of men, who were not very easily controlled. It was stated in evidence, before the Select Committee of the House of Commons appointed to inquire into the subject, that a common shipwright then earned a guinea a day in job work. It was hardly to be expected, therefore, that an officer with so small a salary could resist the combinations of men gaining wages so high, particularly when joined by all the weight and influence of the contractors. The *inspection*, therefore, was a nullity. It was utterly impossible for one individual to examine minutely into all the operations of the great number of men employed at the same time on the different parts of so large a machine as a 74-gun ship. While superintending the work of one gang on one side of the ship, another gang may be employed, to adopt the strong language of a Quarterly Reviewer, "*clenching devils*," as they did in the Albion; or driving "*short bolts*," as was the case in the Ardent; or filling up bolt holes and the rifts in *shaky* timber with paint and putty.

Equally unsatisfactory was the resurvey of the ship when she was received into the King's yards. We quote the reply of the builder and his assistants when called on to explain their conduct with regard to the Rodney.

"The Rodney was carefully inspected by us in the usual manner, and reported that, as far as practicable for us to form an opinion, the works appeared to be executed in a workmanlike manner, and agreeably to the terms of the contract; but it is not *possible for us to form any opinion of the internal parts of the work*, which can be known only to those who inspect the whole of the work in the progress of building."

How very imperfect an estimate is to be formed from the survey of a ship may be collected from the following fact: four 74-gun ships, the Resolution, the Thunderer, the Monarch, and the Culloden, were examined by the Dock-yard officers, and reported as fit to be cut down and converted into razées to be employed against the large American frigates. They were taken in succession into dock for that purpose, but every one of them, on being *opened*, was found unfit for further service, and ordered to be broken up.

That a better system was employed in the King's yards there can be no doubt, and if the ships built in the Royal Dock-yards decayed, it arose from the material necessarily employed, and not from defective workmanship. In *practical* ship-building we surpass every other people; and a good judge of this kind of carpentry need only walk through our Dock-yards, and minutely inspect the ships there building and repairing, to be convinced that the most careful attention is bestowed on this important particular. There is, indeed, so complete a system of inspection and responsibility, as to make it quite impossible to slur over the workmanship in the same slovenly manner as was done in the private yards. The master-shipwright is charged with the general and unremitting superintendence of all the works in each yard; his assistants superintend and control the foremen; they in their turn check the leading men, and the leading men are responsible for the divisions under them. The foremen, being salary officers, have no participation in the earnings of the gang, no interest in the work being slovenly or rapidly performed. On the contrary, the highest responsibility rests on them for its proper execution. An account is taken of every timber and plank that enters the ship, of every hole that is bored, every bolt that is clenched, and every treenail that is driven. The hours of labour are precisely regulated. Every shipwright must be punctual in his attendance, and decent and orderly in his behaviour; and hence it is no fault of the workmen, or of the officers who superintend them, if the ships built in the Royal Dock-yards decay. They can only convert the timber that is in store. The responsibility of providing proper materials rests with a higher quarter: in the times we are alluding to with the Navy Board, at the present time, now that that Board is abolished, with the Admiralty.

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stated in justification of his conduct, "That the unfitness and bad quality of the timber used in that ship, neither were, nor could be discovered by the surveying officers of the yard, as the defects (if any) were always hid by putty, and the surfaces of the beams, knees, riders, &c., covered over with three coats of paint."*

* The magnitude of the evils existing at this time in our ship-building, will amply apologize for the following Reports of the surveying officers of Chatham yard on the state of the Albion, built in a merchant's yard, and alluded to in a former note. Such Reports ought to read a lesson of the strongest kind to the future managers of our Navy.

Extract of a Copy of a Letter to the Navy Board, Chatham yard, April 1, 1811.

The Albion under repair in this yard, from her extraordinary defects, calls for a minute inspection, and a particular description of the causes that may be discovered, that have led to such uncommon complaints, in order to prevent similar occurrences.

We have taken a strake out of her bottom, at the run of the first and second futtock heads, when we discovered that the usual mode of fastening the plank by single and double boring the timbers alternately has not been attended to, a large portion of the timbers being only single bored, of course the ship has been deprived of a considerable quantity of fastenings, and the treenails that are driven appear much crippled from the strain that has been upon them; the plank at the run of the second futtock heads in particular, is not generally in contact with the timbers, nor was it in the first instance, for we discover that it is not in places the proper thickness.

The butts of the wales and the materials above are drawn apart in many places by the hogging of the ship, so that recourse has been had to the letting in of pieces at the butts, to make the calking stand.

In the hold, the foot waling was, from the orlop clamps down, a mass of defective matter; we, in consequence, unbolted the riders, and took it out, when we discovered the timbers of the frame and the opening sodden with filth. Had the ship been sunk in mud, her state could not have been worse; in places she appears to have been a prey to insects of different descriptions, for some of the openings were absolutely full of their remains.

In unbolting the riders, hooks, and crutches, we found many bolts broken, some *short*, and a few termed *devils*, or in other words *false clenches*; in the crutches we also found several bolts *ragged*, which we imagined was done in consequence of their being for an auger of a larger diameter than the bolt required, as rope yarns were wrapped round the bolts so served. A piece of gun-deck spirketing, and also a shift of foot waling was discovered to be chopped in, termed a Spanish burn.

The stern frame of the ship is fallen aft many inches, which may be seen by the carling under the gun-deck beam which rises to the throat of the deck transoms.

The thwartship's arms of the knees of the various decks are twisted from the sides of the beams, many of them sprung so as to be of little use to the ship, and a considerable quantity of the fore and aft bolts broken, many of the beams defective, and departed considerably from their original round, particularly the orlop; in fact, this ship presents a fabric of *complete debility*, arising principally from the *insufficiency of the workmanship*.

With respect to the *devil bolts*, as they are termed, or *false clenches*, we conceive the act so truly criminal, that we are humbly of opinion, that the Legislature should provide a punishment proportionate to the offence.

If it is judged proper to enact a penalty to prevent accidents in cases where the common stages are loaded with passengers beyond a limited number, of how much more consequence is it to prevent acts which may be the destruction of hundreds!

(Signed.) R. SEPPINGS. E. P. HELLYER. W. HUNT.

JOSEPH SPECK, THOMAS PARROTT, RICHARD PRICK, } Carpenters of the { Queen, Ramillies, Albion.

The warrant for the Navy Board ordering the repairs of this ship did not, it seems, embrace all that was necessary to be done; upon which the surveying officers again addressed the Board, as follows:

We can with great truth assure your Honourable Board, that our reason for making the representation was grounded on no other motive than that of doing our duty in a case where *great neglect* has taken place, from which *the Government has sustained a considerable loss, and a ship's company narrowly escaped shipwreck.*

We had flattered ourselves that our survey would have met with your Honourable Board's approbation, and so we humbly conceive it would, but we suspect *representations have been made to counteract what we have stated*; if that be the case, we should be happy to meet those on the spot that have advanced a contrary doctrine. Our suspicions that a different report has been given, arise from the mode of repair you have been pleased to direct; and which mode we consider has been adopted in consequence of representations made by the assistant *surveyor of the Navy*, who has, with the *merchant ship-builders*, visited this yard since our statement.

We have opened her abaft since our survey, by which we have discovered *great additional deficiency of workmanship*, and should contrary opinions have been given to that we have advanced, we are of opinion, those that have offered them should come and view the ship.

(Signed.) R. SEPPINGS. E. P. HELLYER. W. HUNT.

These horrible devils are not confined to the *Albion*. In the surveying officers' reports on the *Ardent* is the following passage: Several of the fore and aft bolts of the gun, upper, and quarter decks, also the forecastle, worked wholly out, and others partly so, in consequence *of many of the bolts being short*; some that worked out were only *five inches, and others nine inches long.*

(Signed.) JOSEPH TUCKER. J. ANCELL. EDWARD CHURCHILL. JAMES JAGOE.

The portion of the second Report, alluding to representations having been made to counteract the statements that had been afforded by the distinguished ship-builders whose names are attached to it, shows at once the nature of the influence that was exerted, and goes far to explain the abominable practices that prevailed in these private yards where King's ships were building.

(381.) In the Journal of Lord Sandwich's visitation of the Dock-yards in 1771, the following passage occurs. "Went on board the Ardent, found her in a total decay, her timber and plank rotted almost universally. This ship was built at Hull in 1764, and never was at sea; her prime cost was about £23,000, and her repairs are now estimated at £17,000. The cause of the great decay of this ship is attributed to her being hastily built." His Lordship adds: "no more ships to be built at Hull." Happy would it have been for the Country could this injunction respecting Hull have been extended in an after-time to all the private yards in the Kingdom; or if the necessities of the Kingdom required their assistance, that an effectual superintendence of them had been rigidly enforced.

Remarkable entry in the Journal of Lord Sandwich.

(382.) We have had so many examples of great durability in our Navy, that our regret at these instances of decay, cannot but be augmented when we reflect on them. The Royal William, a first-rate, built at Portsmouth in 1719, was among the ships sent to the relief of Gibraltar in 1782, and after the lapse of nearly a century, bore the flag of the Port Admiral at Spithead. The breaking up of this fine old ship was an object of considerable curiosity. Various reasons had been assigned for her extraordinary durability. It was supposed that her timber had undergone some artificial seasoning, that the plank and thick stuff had been burned instead of kilned, the ends and surfaces of the various parts charred, and that the process of *snail creeping*, or gouging out, in crooked channels the surfaces of the timbers and planks, was made use of to give a free circulation of air. It is understood, however, that no indications of charring, burning, or snail creeping could be traced, and that her timbers had undergone no other preparation than that of time and the weather. This remarkable vessel was built by Mr. Nash, and he took particular care when building her to employ only well-seasoned materials. It is also a singular fact in the history of this ship, that owing to an ignoble jealousy which existed between her builder and Sir Jacob Ackworth, Sir Jacob endeavouring in all things to lessen the merit of Mr. Nash, the Royal William was not for

Many examples of great durability of ships. Royal William.

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many years employed, and even a decree was on one occasion made for making her a hospital ship. "Thus," said Lord Sandwich, "that ship which has proved to be of as good qualities as any ship that was ever built, was lost to the public for many years, owing to a jealousy and ill will between two officers. Such feelings are the ruin of many great undertakings, and in the public departments ought to be checked in every possible way."

Sovereign of the Seas.

(383.) The Sovereign of the Seas, afterwards named the Royal Sovereign, was built at Woolwich in 1637, and stood forty-seven years' service. The Barfleur was built at Chatham in 1768, and in 1812 was still a good ship and under repair for further service. The Montague was launched at Chatham in 1779. After undergoing several repairs, she carried the flag of Admiral Sir Manly Dixon, the "Hero of the Lion" as he is called by the sailors, at Rio Janeiro. How different these examples from the Ocean, the Foudroyant, the St. Domingo, the Rodney, the Ajax, the Albion, and many others, which were falling to pieces within five years after launching, and some of them in less than three!

Satisfactory state of the British Navy at this time.

(384.) It is a consolatory reflection, however, after the really appalling considerations we have felt it our duty to go through, to state, that at the present time, the state of the British Navy is such as to warrant the most complete satisfaction in the general efficiency and soundness of our ships. The constant assertions of those authorities, whose situations make them necessarily acquainted with the general state of the Navy, and whose unremitting attention renders them most intimately acquainted with the minutest details of his Majesty's ships, are abundantly sufficient to remove every fear which its condition fifteen or twenty years ago could not but inspire.

Precautionary measures that have been adopted.

(385.) This great and desirable change has been brought about by various precautionary measures adopted by the late Navy Board, after reviewing all the plans that had been proposed by different ingenious individuals.* The methods at present adopted in his Majesty's Dock-yards for the preservation of timber, are such as have been suggested by an examination of its nature, and the circumstances under which it is placed in ships, and which have been proved by experience to have been well calculated to produce this desirable effect.

Placing timber under roofs and not in contact.

The principal of these—the placing timber under roofs, and keeping the logs apart from each other, is found an excellent method of seasoning timber, by admitting a free circulation of air without an exposure to the rain.

Immersion of timber in fresh and salt water.

Immersion of timber in water also is found to be an expeditious method of drawing out the juices of the wood; and salt water has been preferred to fresh, on account of the antiputrescent power of salt, which, though less effective on vegetable than on animal matter, is useful in checking the decay of timber.

Removing sap.

Also taking off the sap, which speedily becomes rotten, and preventing the communication of the decay to the adjoining heart wood.

Coating surfaces with tar.

Covering, likewise, the surfaces of timber with mineral tar or paint, thereby keeping the timber from being rent by the air, and preventing the seed of the fungus, which *may* be in the outer laminæ of the timber, from vegetating, by the exclusion of the atmospheric air from it. It is also particularly useful when two kinds of timber are brought together, by preventing the fermentation which would arise from the union of different vegetable principles.

Injection of tar.

The injection of tar and whitening into ships' bottoms, has been found also of very great benefit in preserving the timbers, by its preventing effectually the growth of the fungus; the openings between the timbers, which would otherwise be imperfectly filled, and the rents in the timbers, in which places the seed of the fungus would be most likely to vegetate, being by this means completely filled, the air, so necessary to vegetation, is excluded. It is probable that the great advantages of the injected tar, &c., into the interstices of the wood, are not yet fully known.

Building and repairing ships under roofs.

(386.) In addition to these preventives, ships are built and repaired under roofs, thereby preventing the rain from settling in the rents of the timbers and the openings between them. In the ships in ordinary, also, particular attention has been paid to their preservation, by erecting temporary roofs over them, taking down parts of the bulk heads in the hold, and leaving out streaks in the decks and openings in the truss work, between the ports, to promote a free circulation of air.

Free currents of air.

(387.) It is proper to observe, however, that the establishment of a free current of air through a ship, though of very great advantage in preventing decay, is, nevertheless, attended with the disadvantage of causing the timber to shrink, thereby impairing the strength of the fabric, by destroying in some degree the benefits arising from fitting the pieces of work closely together, technically called "faying well." The maximum advantage is therefore obtained by giving such a circulation of air as may be sufficient to prevent decay, without causing the timber to shrink too much. Experience is tending fast towards the discovery of the proper limit, towards which this principle may be carried with the greatest advantage to the service.

German oak timber very subject to dry rot.

(388.) The oak timber produced in the forests of Germany is remarkably subject to the dry rot. Hence the ships in the Scheldt, during the latter part of Buonaparte's career, were rapidly advancing in rottenness from this cause. The Chatham, a 74-gun ship, had the dry rot in her timbers when taken from the stocks in the Dock-yard of Flushing. The Rivoli, just off the stocks, at Malamacca near Venice, was also in the same state. This latter ship was built of oak cut from the Eastern shores of the Adriatic.* Foreign ships, therefore, are

* We are far from applying to those plans, and to their authors, those terms of indiscriminate censure which by many writers have been so abundantly directed to them. It is true that many, perhaps the great majority of them, were visionary, but their authors deserve at least the praise of endeavouring to do well, and of checking an alarming evil. What would have been our condition, had the public felt no interest in the welfare of its Navy, had the national spirit been so degraded, so morbid, and so dead, that it regarded neither the destruction of the natural bulwarks of the Country, nor the consequences to which so fearful a state of things must have led? This keen interest respecting our political state, and the maintenance of our national glory and honour, is surely an index of a healthy state of the public mind.

* It is remarkable that the Rivoli was built of oak which had been paid for by this Country, and brought down to the sea-coast at our expense to be shipped for England. The defection of Austria at this juncture put the French however into possession of it, the timber having been unfortunately placed in a most convenient situation for the use of their Naval Arsenal near Venice. Though the English paid for the timber, the French paid for putting it together and fitting out the ship.

The Rivoli was floated out of the harbour over the bar that crosses the passage about midway, by means of a camel or water-tight box, resembling those used at Amsterdam and St. Petersburgh. The departure of the ship was anxiously watched by Captain John Talbot, in the Victorious of 74 guns, and the Weazle brig of 18 guns, Captain Andrews. The English ships arrived off Venice on the 16th of March, 1812, and on the 21st got sight of the Rivoli. She was attended by a large ship, two brigs, and two

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as much subject to the inroads of dry rot as our own; and we may perhaps say, more so.

Other causes of decay. Marine animals attack the bottoms of ships.

(389.) Ships, however, are subject to other causes of decay, besides those already enumerated. Marine animals attack the planking in every vulnerable part, and sometimes occasion the most alarming evils. In some climates, particularly in the East and West Indies, on the coast of Africa, and in the Mediterranean, the destruction of timber is found to be much more rapid than in others, from the abundance of these animals infesting those seas. The danger to be apprehended from them there is very great; and indeed it is every where unsafe to allow any part of a ship's bottom to remain unprotected from their attacks.

Investigations of Mr. Willcox.

(390.) According to Mr. Willcox the most destructive of these marine animals are the Teredo, the Pholas, and the Lepisma. The former genus is most to be dreaded, and is said to have been originally imported from India It penetrates the hardest wood, and increases gradually in size as it proceeds in the work of destruction, until the part attacked by it frequently becomes like a honeycomb. It is but rarely that they bore through, although they frequently approach the inner surface within a very short distance, leaving a substance not thicker than the twentieth of an inch from the inside.

Extreme danger from the attacks of these animals.

There is an instance connected with the Sceptre of 74 guns, which fully proves the extreme danger of their attacks. This vessel left Bombay for England in 1807, and after being some time on her passage, was obliged to return in consequence of a serious leak proceeding from her bow. On examining her, it was found to have resulted from some of the copper having been rubbed off, and the parts of the bottom and the gripe thereby exposed being attacked by the Teredo, which had penetrated these places to so great an extent as to render her quite unsafe to pursue her voyage, without putting on new planks on the bottom, and shifting the gripe. The species of Teredo most commonly found in ship's bottoms is the *Teredo Navalis*.

gun-boats steering towards the port of Rota, in Istria. The Victorious and Weazle gave chase, and at a quarter past four in the morning, the Weazle being a head, brought the two brigs to action. At five, the Victorious being within pistol-shot of the Rivoli, a furious action began. Soon after, one of the enemy's brigs blew up, and at daylight, Captain Talbot saw the Weazle in chase of the other, but recalled her, perceiving she did not gain upon the enemy. The other ships and the gun-boats were not in sight, and the contending ships being in seven fathoms water, off the Point of Grao, Captain Talbot thought the brig would be of more service near him, in case of either ship getting on shore. Captain Andrews placed his brig within pistol shot on the bow of the Rivoli and gave her three broadsides. It was now nearly calm, and the action had lasted four hours. The fire of the enemy was very faint, and at a quarter before nine she surrendered. She bore the broad pendant of Commodore Barré, the Commander-in-chief of the enemy's force in the Adriatic.

At no period of the action were the two line of battle ships at a greater distance than half musket shot from each other. The Commodore did not surrender until nearly two hours after his ship had become unmanageable. His mizen mast fell just before he struck his colours, when his captain, most of his officers, and 400 of his men were killed or wounded. The loss on board the Victorious also was very great. She had 42 men killed and 99 wounded. The Rivoli had on board 892 men at the commencement of the action, but the Victorious no more than 512, of whom 60 were in the sick list. Captain Talbot received a medal for this action, and, subsequently, was made a Knight of the Bath. Captain Andrews was made Post, and Lieutenant Peake of the Victorious a Commander. It is a curious fact, that after the valuation of the Rivoli, no less a sum than £13,000 was deducted from the proceeds for damages done to the ship in action.—Brenton, *Naval History*.

Thus though we at first lost the *timber* which had been paid for by British money, by the defection of Austria from the common cause, the gallantry of British sailors added the ship which had been *constructed* with French money to the Navy of England, with a large share of glory in addition.

On the Tonnage of Ships.

Tonnage. Origin of the present erroneous rule.

(391.) The rule commonly employed for finding the tonnage of ships is open to the most formidable objections. Founded on error, it opens a door to deception and fraud, and even the good qualities of merchant ships have been sacrificed to the desire of obtaining excessive ladings, which this rule largely encourages. It owes its origin to the 13 Geo. III. cap. 74, which declares that "the length shall be taken in a straight line along the rabbet of the keel of the ship; from the back of the main stern post to a perpendicular line from the fore part of the main step under the bowsprit. The breadth, also, shall be taken from the outside of the outside plank, in the broadest part of the ship, either above or below the main wales, exclusive of all manner of doubling planks that may be wrought upon the sides of the ship." In cases in which it may be necessary to ascertain the tonnage of vessels afloat, it was further declared by 26 Geo. III. cap. 60, that to obtain the length, the measurer is to "drop a plumb line over the stern of the ship, and measure the distance between such line and the after part of the stern post, at the loadwater mark; then measure from the top of the said plumb line in a parallel direction with the water, to a perpendicular point immediately over the loadwater mark, at the fore part of the main stem, subtracting from such admeasurement the above distance; the remainder will be the ship's extreme length, from which is to be deducted three inches for every foot of the load draft of water for the rake abaft." Then by 13 Geo. III. cap. 74, and 26 Geo. III. cap. 60, "from the length taken in either of the ways above mentioned, subtract three-fifths of the breadth taken as above, the remainder is esteemed the just length of the keel to find the tonnage; then multiply this length by the breadth, and that product by half the breadth, and dividing by 94, the quotient is deemed the true contents of the lading."*

Algebraic expression of this rule.

(392.) This rule expressed in algebraic language,—the only language in which rules should at any time be delivered, is

$$\frac{L \times B \times \dfrac{B}{2}}{94} = \frac{L \times \dfrac{B^2}{2}}{94},$$

where L represents the length, and B the breadth.

(393.) By this rule the whole of the vast tonnage of the British Naval and Commercial Marine is computed. Instances without number might be given of the errors

* According to Mr. Parsons, the origin of this rule is as follows: A body floating in a fluid displaces a volume of that fluid, the weight of which is equal to the whole weight of the floating body. This displacement must always bear some relation to the principal dimensions of a ship, denoted here by L, B, and D. It has been found, that in vessels of rather full forms, the displacement estimated in cubic feet of sea water, is equal to sixty two-hundredths of the product of these three dimensions; which being divided by 35, the number of cubic feet of salt water in a ton, will give

$$\frac{L \times B \times D \times .62}{35}$$

for the displacement in tons.

The draught of men of war is generally about half the extreme

it occasions. Even by calculating the tonnage of the same vessel by the two methods above given, the results will be very different. Thus if we take the cutter given by Mr. Parsons in his *Scales of Displacement of the British Navy*, and apply the first method, the length to be taken will be 52.25 feet, and the tonnage 160 tons; but if measured by the second method, which involves the length of the water line, and is here found to be 50.4 feet, the tonnage will amount only to 154 tons. If, moreover, the rake of the stern post be increased, and the rake of the stern diminished, the water line remaining unaltered, the length by the keel will be only 48.5 feet, and the tonnage 148 tons. And supposing on the contrary the rake of the stern post to be diminished, and the rake of the stern increased, the length by the keel will then be 58 feet, and the tonnage 177 tons. But all the cases when measured afloat, or by the water line, will give a tonnage of 154 tons. Thus in so small a vessel as a cutter, a variation of 29 tons may be made in the register of the vessel, without any sensible difference in its real capacity, while the absolute weight this vessel can carry under all the above circumstances amounts only to 90 tons.

Instance of its errors.

(394.) In like manner the length of the keel may be constant, and the water line vary, by altering the rake of the stern and stern post. Even the form of the head of the rudder will alter the tonnage of a vessel; for if a round headed rudder be substituted for one of a square headed form, the back part of the post being taken off to receive the round head, the water line becomes immediately shortened, and the tonnage, as a necessary consequence, diminished.

(395.) It has been observed, also, that by omitting the draught of water in the rule, the practice of increasing the depth has become general, by which means vessels are capable of carrying a greater burthen without increasing the tonnage;* nor is this the only defect, a far greater one existing by omitting to take the form of the vessel into consideration. This error in the rule operates to such an extent at the present time, as to make the register tonnage of merchant vessels amount generally to two-thirds only their absolute burden. This excess of the absolute burden above the register tonnage, results entirely from the form, and is found to vary in almost every vessel, even where the principal dimensions are the same; and as the present rule for tonnage is entirely independent of the form of the vessel, the excess is entirely exempt from dues. Should the dues be laid on the apparent tonnage, with reference to this excess, the objection will not be removed, since the excess is not constant. The register tonnage of men of war is considerably greater than their absolute burden.

How the rule may be evaded.

(396.) These, and similar methods, open a boundless scope for evasion and fraud, according to the peculiar views of the builder or owner of the ship. This is, at once, a sufficient reason why the rule should be improved; for where can be the wisdom of that legislation which opens a door to dissimulation and deceit in any form?

Method employed by the French.

(397.) Different nations employ different rules for the admeasurement of tonnage. The French add the length of the deck taken between the rabbets to that of the straight line of the keel, and take half their sum. This quantity is multiplied by the greatest breadth at the midship beam, and that product by the depth of hold and height between the lower and upper decks, the whole product being divided by 94. If the vessel has only one deck, the greatest length of the vessel is multiplied by the greatest breadth in midships, and that product by the greatest height, the whole being divided by 94. This rule is simple, but very erroneous. A certain depth of the vessel is taken as a third dimension, but it is altogether independent of the immersion produced by the lading, *viz.* the depth from the load to the light water line, and which is most essential to be considered. This depth, it is evident, may vary very considerably in two vessels whose ladings are the same. One may be much deeper than the other, from a greater rise of floor, the total displacements of the two vessels remaining the same; and this depth may also vary from the decks being placed at different heights in the two vessels. The different forms of body are also totally neglected in this method of measurement.

Method of the Chinese.

(398.) The Chinese take only two dimensions for finding the tonnage of ships, the length from the centre of the mizen mast to the centre of the fore mast, and the extreme breadth close behind the main mast. These dimensions are multiplied together, and the result divided by 10 gives the tonnage. This method of measuring shipping for the purpose of charging duty is very favourable to large ships.

Method of the Americans.

(399.) For measuring the tonnage of merchant ships in the United States of America, the 64th section of an Act of Congress, approved March 2, 1799, declared, "That to ascertain the tonnage of any ship or vessel, the surveyor, or such other person as may be appointed by the collector of the district to measure the same, shall, if the said ship or vessel be double-decked, take the length thereof from the fore part of the main stem, to the after part of the stern post, above the upper deck, the breadth thereof at the broadest part above the main wales, half of which breadth shall be accounted the depth of such vessel; and shall then deduct from the length three-fifths of the breadth, multiply the remainder by the breadth, and the product by the depth, and shall divide this last product by 95, the quotient whereof shall be deemed the true contents or tonnage of such ship or vessel.

breadth of the ship, and at the time of the formation of the rule, the same relation probably existed in merchant ships. If, therefore, $\frac{B}{2}$ be substituted for D, the preceding expression will become

$$\frac{L \times \frac{B^2}{2} \times .62}{35};$$

and as the weight of the hull, stores, &c., was generally about two-fifths of the whole weight, leaving three-fifths for the weight of the cargo, we shall further obtain

$$\frac{L \times \frac{B^2}{2} \times .62}{35} \times \frac{3}{5} = \frac{L \times \frac{B^2}{2}}{94},$$

for the burthen in tons, which is the common rule.

* It is a curious fact, that a ship, which, in the port of London, was put into dock for the purpose of being raised upon, so as to increase the capacity of stowage, before going into dock, admeasured more than *after she had been raised upon*, although by the alteration she acquired the capacity of carrying nearly 100 tons more than she could have done previously to such alteration. On re-survey, she measured *less* when she came out of dock, than under her old register, although 100 tons larger. The ship in being raised upon was rather *narrowed* in her width; the consequence of which was, that the increased depth of hold not being included in the calculation of her tonnage, she became less in tonnage by admeasurement to what she was at the time of the original register being granted. *Edinburgh Review*, No. 90. p. 456.

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And if such ship or vessel be single-decked, the said surveyor, or other person, shall take the length and breadth as above directed, in respect to a double-decked ship or vessel; shall deduct from the said length three-fifths of the breadth, and taking the depth from the under side of the deck-plank to the ceiling in the hold, shall multiply and divide as aforesaid; and the quotient shall be deemed the tonnage of such ship or vessel."

(400.) These rules appear to have been derived from the English and French rules: the first, for double-decked vessels, being nearly the same as the English, and the latter, for single-decked vessels, being nearly the same as the French. They respectively possess the inaccuracies of each, with the additional error of being inconsistent with each other.

Swedish rule.

(401.) In 1778 the Swedish government adopted the following rule:

"1. All mensuration is to be done by the Swedish foot, and the vessel's burden is to be marked down in lasts, each to be considered in weight equal to 18 skeppund, iron weight, or eighteen times 320 pounds Swedish. 2. The vessel's length is to be measured on the highest water line, when loaded, from the fore part of the rabbet of the stem to the aft part of the rabbet of the stern post. 3. The ship's breadth is to be measured in midships without board, close up to the main wale. 4. The height is to be measured from the surface of the water without board, up to that mark which determines how deeply the vessel will swim when completely loaded. 5. These three admeasurements are to be multiplied together, and the product divided by 112, should the vessel be of the usual shape, and neither too full nor too sharp at the stem and stern. If the vessel is sharper, the divisor must then be greater, and if fuller a little less, as pointed out to the measurer in the separate instructions. 6. If the necessary provision, water, wood, and utensils for the voyage be not on board when the ship is measured, and which weight does not actually belong to the burden the vessel is measured to carry, it is then necessary to deduct from the calculated burden of lasts as follows:—on a vessel of 350 lasts is allowed 11 lasts deduction; (corresponding deductions are given for vessels decreasing in burden from 350 to 40 lasts;) and so on in proportion, in such vessels as are not coincident with the above denomination. But should any of the articles mentioned be on board, the deduction will be less in proportion. 7. Should one or more of the necessary cables not be on board when the vessel is measured, the following deductions are to be made: for an 18-inch cable 25 skeppund, iron weight. (The deductions for smaller cables, down to a four-inch cable, are specified.) 8. Should one or more anchors be wanting, their weight is to be deducted in proportion to the vessel's size. 9. If the vessel's sails are not on board, the deduction from its number of lasts is to be as follows: on a vessel of 350 lasts, 14 skeppund, iron weight. (Corresponding deductions for the sails of smaller vessels, down to those of 40 lasts, are given.) And less in proportion when fewer sails are wanting. 10. If the vessel is built to carry guns constantly, and that none, or part of them only, are on board, a deduction for cannon, carriages, gun-tackling, &c. is to be made as follows: for a 12-pounder, with its requisites, 13 skeppund, iron weight (with corresponding deductions for smaller guns.) 11. Should the vessel, when measured, have its ballast on board, then that weight must be ascertained, and added to the number of lasts found; but it is best to measure the vessel before it is ballasted, if convenient. 12. The ship's measurer having duly considered the foregoing circumstances, and in consequence thereof ascertained the vessel's proper tonnage to a certain depth, fore and aft, when loaded, he is then to make an entry of the foregoing in the book of admeasurements given him for that purpose, which book is run through and sealed with the seals of the Court of Aldermen and Custom House: he is also to enter the number of lasts requisite to immerse the vessel, progressively, from one foot at the beginning of the loading till when completed, and also to set down how deep she lies fore and aft when unloaded. He is to deliver copies of the same, with specific calculations, admeasurements, and deductions of all this, to the Court of Aldermen and Board of Customs, within two days after measured, that the same may be examined and sanctioned. 13. Should there be any thing to be observed by the parties, the same must be made known at the respective places, within eight days after the delivery, at the expiration of which time the ship's register will be made out, and the approved calculation of the measurer annexed to the same, and to be kept on board as the ship's inventory. The same is to be entered, with all the calculations, in bound paged books, and alphabets thereunto annexed, in the Court of Aldermen and at the Custom House. 14. Whereas vessels, when old, and soaked through by the water, cannot carry so much as when new, it is therefore requisite to measure the vessel every tenth year, in like manner as expressed in the twelfth section."

Divisions into seven classes.

(402.) In the instructions alluded to in the fifth section, vessels are supposed to be divided into seven classes, according to their fulness or sharpness; and corresponding divisors are given, obtained by calculations from different vessels. These divisors vary for the whole depth immersed by the lading, from 104 for the fullest, to 122 for the sharpest vessel; and the divisors to be used near the load water line vary from 98 to 104, and near the light water line, or discharging line, from 108 to 133.

(403.) Mr. Morgan remarks on this rule, that it is strictly correct in principle, and that the only error which can arise in practice, is in the divisor being left to the determination of the measurer. A skilful measurer, after great practice, will be able to determine the divisor with ease and certainty.

Rules of Mr. Parkin.

(404.) Mr. Parkin has given two rules for calculating the tonnage of ships, published in *The Shipwright's Vade Mecum:* one for ships of the Royal Navy, and the other for merchant ships. The following is his rule for merchant ships:—1. "Find the length of the lower deck, from the rabbet of the stem to the rabbet of the stern post, and take $\frac{1}{1}\frac{1}{2}$ of this length for the *keel for tonnage.* 2. To the extreme breadth add the length of the lower deck, and take $\frac{1}{35}$ of this sum for the *depth for tonnage.* 3. Set up this depth from the limber strake, and at that height take a breadth also from out to out of the plank at dead flat. Take two more breadths, one at two-thirds, and the other at one-third of the height. Add the extreme breadth and these three breadths together, and take one-fourth of the sum for the *breadth for tonnage.* 4. Multiply the length, depth, and breadth for tonnage continually together, and divide the resulting product by $36\frac{2}{3}$, which will give the burden in tons." This rule seems to make a little approach towards the true measure-

ment of tonnage, but it is not founded on correct principles.

Chapman's rules.

(405.) In 1792 Chapman furnished two rules on this important subject. The first was an approximate rule, relating to the payment for the building of ships. "The cost of a ship," he says, "is nearly in proportion to its outer surface multiplied by the thickness of its sides; but as this thickness may be considered in proportion to one of the dimensions, so it may be judged that the product of the length, breadth, and depth gives the proportional costs. A difficulty, nevertheless, attends this, because the length and breadth can be precisely fixed, but the height or depth cannot. For instance, if the depth of the hold be used as the third dimension, it may happen, in consequence of the cargo which the vessel is to carry, that the lower deck has been laid a foot higher or lower, although its length, breadth, and the whole of the height remain the same; the expense of building, as also the burden, remain the same; but the difference of the height of the deck increases or decreases the product, and consequently the cost in proportion. The same thing takes place with regard to the upper deck. Should the height of the vessel from the keelson to the gunwale be taken as the third dimension, it will be found to vary just as much as the former. For example, the gunwale might be made half a foot or a foot less in height, and this quantity added to the gunwale after the ship is built, which of course would make it cost less than if that height was included in the calculation. If that part of a ship which is immersed when loaded should be taken as the third dimension, the question to be considered would be how high the water line stands marked on the draught up to which the ship ought to be loaded, which might also be higher or lower. It is, therefore, better to institute a rule which, although not totally exact, is still not subject to disputes or confusion.

"I therefore propose," says Chapman, "that the ship's height or depth should be taken so as to bear a proportion to two dimensions, namely, as the square root of the product of the length and breadth. If now the length and breadth be expressed by L and B, then must the depth bear a certain relation to $\overline{LB}|^{\frac{1}{2}}$, without regarding how great that quantity may be. This multiplied by the length and breadth, the number of tons will be proportional to $\overline{LB}|^{\frac{3}{2}}$. This expression represents the solidity, and in which two of the principal dimensions are equally involved. To apply it to the determination of a ship's burden, it will be necessary to find what proportion the breadth bears to the length, agreeably to the old method of determining the tonnage when the contract has been equally beneficial. Suppose the breadth to have been $\frac{53}{200}$ of the length, or the length to be 100 feet when the breadth is $26\frac{1}{2}$ feet. According to the old method,

$$\frac{\left(100 - \frac{29}{40} \times 26.5\right) \times \frac{26.5^2}{2}}{94} = 301.78 \text{ tons};$$

whence

$$\frac{(100 \times 26.5)^{\frac{3}{2}}}{x} = 301.78, \text{ and } x = 452.$$

Hence the tonnage of a ship ought always to be expressed by $\frac{\overline{LB}|^{\frac{3}{2}}}{452}$."

This divisor, 452, is subject to alteration according to circumstances.

(406.) Chapman's other rule is for the correct determination of the weight of the lading a ship carries. This rule is similar to that given by the Swedish Government, except that the divisors are adapted to the English ton, instead of the Swedish skippund. He gives a table for ten classes of vessels according to the fulness or sharpness of their bodies, in which the divisors vary from 39 in the fullest, to 48 in the sharpest vessel. He takes the extreme length on the load water line L, the extreme breadth just below the main wale B, and the mean depth between the light and load water lines. The product of these three dimensions, divided by D, the variable divisor in his table, gives the lading in tons.

Another rule.

(407.) A rule for the measurement of tonnage has been given which approximates nearly to the true weight of lading, by multiplying together the length of the load water line between the fore part of the rabbet of the stem and the after part of the rabbet of the stern post, the greatest breadth, and the mean depth between the light and load water lines; taking three-fourths of the product, and dividing by 35. To this sum is added an allowance in proportion to the fulness of different bodies, determined by actual measurement.

Another example of the error of the common rule.

(408.) In the *Shipwrights' Repository* the error of the rule commonly employed is clearly explained, and the true tonnage shown to be the difference between the total weight of the ship to the load water line, and the weight of the hull and furniture. The author has given several examples of the tonnage of ships: the following is the result of his calculations of the tonnage of an 80-gun ship:

	Tons.	lbs.
Weight of the ship at her launching draught of water	1593	406
Weight of the furniture	195	720
Weight of the ship at her light water mark	1788	1126
Weight of the ship at her load water mark	3554	356
From which deduct the weight at light water mark	1788	1126
Real burden	1765	1470
Burden in tons by common rule ...	1959	929
Real burden	1785	1470
Error....	193	1699

(409.) The real burden of this ship is therefore 193 tons less than her computed tonnage. In an East Indiaman, his result shows that the real burden was 178 tons more than her computed tonnage. In other examples the differences are still greater.

(410.) Chapman, Clairbois, Atwood, and latterly Mr. Parsons, have calculated and drawn scales of tonnage for particular ships. The latter has made the calculations and drawn the scales of tonnage, for most of the classes of ships of his Majesty's Navy, and for twenty-one classes of vessels of the British mercantile Navy.

Mr. Parsons's labours on this subject.

(411.) Mr. Parsons's scales of tonnage are drawn for all these vessels from the keel to the gunwale. Each vessel is divided into fore and after bodies, by a vertical line proceeding from the middle of the length of the

Naval Architecture. Scale of tonnage.

load water line, between the fore side of the rabbet of the stem and the aft side of the rabbet of the sternpost; and a separate line of tonnage is drawn for each body. The solid content of the body in cubic feet, at different heights, is calculated by sections parallel to the keel, which being divided by 35, the number of cubic feet of sea-water in a ton, gives the weight of water which would be displaced at those heights. By setting off from a vertical line, on lines parallel to the keel, these results by a scale of tons, spots are obtained, through which the line of tonnage may be drawn. By setting up, moreover, any height on the vertical scale of feet, and drawing a horizontal line at that height, it will represent the weight of the corresponding displacement, and which is found by transferring it to a scale of tons placed horizontally over the figure. By taking, also, the heights of the light and load water lines of any vessel, and transferring them in this manner to the scales of tonnage, their difference will give the weight of the displacement between the light and load water lines, or the true weight of lading. The mean depths are taken for each body separately, and the sum of the two parts thus found gives the total tonnage.

(412.) By these lines of tonnage may be ascertained the weight put on board, or taken out of a vessel at any time, by observing the different draughts of water, and measuring the tonnage or weights corresponding to them. The difference of these weights will be the quantity put into or taken out of the vessel. For example, in a cutter of 160 tons, when ready for sea with all her stores, the draught of water is 8 feet 9 inches forward, and 13 feet 6 inches aft, the mean being 11 feet 1½ inches. The mean depth, also, for the after body is 12 feet 3¾ inches, giving 93 tons for its weight. The mean depth for the fore body is 9 feet 11¼ inches, giving 83 tons for the weight of that body, making the whole displacement 176 tons. The weight of the hull when launched having been 82 tons, the difference on the weight put on board must be 94 tons.

(413.) This method of taking the mean depth in each body, though most correct, will seldom be necessary, because if the mean depth of the extremities be used alone for each body, it will give nearly the same result. The tonnage is then measured by taking the mean depths of each body separately, and the difference of the results of the two methods is found to be only one ton. In vessels having a less difference of draught of water, the error is proportionally less. On this account, the mean depths of the load and light draughts of water are used in the scales of tonnage, which supposes the vessel to swim on an even keel, at the mean draught of water in each case.

Remarks.

(414.) In considering the practical benefit of the scales of tonnage, observes Mr. Morgan, it is necessary to examine the difficulties which would attend their application. This method of measuring the tonnage of ships is strictly correct, assuming the light and load draughts of water to be known; but it is in the practical determination of these lines that the difficulty exists. Mr. Parsons has assumed the launching draught of water as the light draught; and this is the easiest method, but not the most correct. The tonnage should express the lading which can be put into a ship, when every necessary article of furniture and stores is on board, in order to bring her down to its load draught of water. The two Swedish methods given above removes this difficulty, by taking the light draught of water, when every thing is on board except the lading; an established allowance being made for every article not on board at the time. This method may be attended with trouble, in obtaining the weights of the different furniture and stores; but it is the only mode of determining the correct light draught of water, which is the first element necessary in measuring a ship's tonnage. The next difficulty, and by far the greatest, is the determination of the load draught of water. Two methods suggest themselves of accomplishing it. It may be determined by officers appointed for the purpose, the moment a ship is built, and the result inserted in the register, by which draught of water the tonnage may be measured. The objections to this method are, the liability of the load draught of water being incorrectly determined either by fraud or ignorance, and afterwards requiring alteration; and the opportunity it affords the owner of taking on board, at his own risk, a greater lading than that for which his ship was registered. Experience may, however, render the officers capable of ascertaining the load draught of water with considerable accuracy, and fines may deter the owner from incurring the risk of loading his ship deeper than it was constructed to swim with safety. Another method of obviating the difficulty, is by a ship's always paying duty on the quantity of lading on board; so that the measurement of tonnage may be taken at the actual draught of water at which the ship swims when it comes into port. This would render the load water line at first determined little more than nominal: it would allow a vessel's being spoken of as having a nominal tonnage, producing no error in the measurement of the real tonnage on board. Either method will render these scales of tonnage applicable to general use; but the latter may be preferred, because it brings the correct principle of measuring the true lading fully into practice.

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(415.) It is probable that tables of tonnage may be preferred by many to scales of tonnage; but as their principle and use would be the same, the preference is indifferent. It may, also, be observed, that if the whole displacement were represented by one scale, instead of being divided into two parts for the fore and after bodies, the use of these scales would be more simple in their application to the tonnage of ships, although less useful for general purposes of design.

(416.) Mr. Parsons has applied scales of the exterior surfaces founded on the dimensions, scantlings, &c. of ships to the determination of their charges for building. Any surface of this kind multiplied by the mean thickness of the ship's side, would give a tolerably correct measurement of the quantity of materials. As the expense of building vessels must be in proportion to their outside surfaces, these lines will be a much better criterion for estimating the expense than the register tonnage.

Example of Mr. Parsons's mode

(417.) Fig. 10. pl. ii. is an example of Mr. Parsons's mode of finding the tonnage of a brig of 170 tons, register tonnage. Suppose this vessel to have every thing on board except the cargo, and her draught of water to be six feet at the stem and sternpost, or on an even keel. Set this distance up from the base line, or lower side of the false keel, and draw the line A 12 parallel to the base, intersecting the line of tonnage 1 for the after body in B. Then will the distance A B applied to the scale, measure 46 tons, the weight of the after body. The same line intersects the line of tonnage 2 for the fore body in C, giving for A C 64 tons, the

weight of the fore body. The whole weight of the vessel with every thing on board, excepting the cargo, is therefore 110 tons. Suppose now the cargo to be put on board, and the draught of water 12 feet at the stem and stern post. At 12 feet from the base draw D 11, which will give for the corresponding weight of the after body 157 tons, and for the fore body 193 tons, giving for the whole weight 350 tons. The weight before the cargo was put on board having been 110 tons, the weight of the cargo itself must be 240 tons. When there is a considerable difference in the draught of water at the stem and sternpost, Mr. Parsons recommends the medium depth to be taken for each body, instead of the depth in the middle of the vessel.

Other properties of the figure.

(418.) The other lines in the figure have some useful properties. That marked 3, for example, denotes the whole area of the horizontal sections in square feet of the after body, and that marked 4 in the same manner for the fore body. The line denoted by 5 represents the whole exterior surface of one side of the vessel, in square feet, of the after body, and the line 6 of the fore body. The line 7 is for the whole area of the vertical sections, as high as the load water sections, in square feet, of the after body, and the line 8 for the fore body. ⊕⊕ gives the situation and form of the principal transverse section; 9, 9 the situation and form of the section in the after body, whose area is equal to two-thirds the area of the principal section, and 10, 10 in the fore body. 11 and 12 represent the load and light water lines. An analytical investigation of the properties of these singular curves would be likely to lead to some useful and important results.

Present rules operate against improvement of mercantile marine.

(419.) The facility which the ordinary rules for finding the tonnage affords for the evasion of dues is not the only evil attending it. It unfortunately operates against any improvement in our mercantile marine. Great capacity with small dimensions is now the primary object of consideration; and this is too often obtained by sacrificing expedition and safety. If the tonnage gave a true measure of the capacity of the ship, there would be no cause why the mercantile Navy should not equal, or indeed excel, the military in every quality of safety and velocity; whereas it is a well-known fact, that the British merchant shipping is inferior to that of almost every trading Country in the World.

Labours of Society for Improvement of Naval Architecture.

(420.) Attempts have not been wanting to improve these imperfect modes of determining the tonnage, but hitherto without success. In 1791 the Society for the Improvement of Naval Architecture offered a premium of twenty guineas, and a silver medal, for the most ready and accurate method, by approximation or otherwise, for determining the tonnage of vessels and ships of every description, from an admeasurement of all the principal dimensions. The two rules of Chapman, before adverted to, were given in consequence of this invitation.

Report of a Committee in 1821. Another appointed in 1832.

(421.) On the 24th of May 1821, a Report of a Committee consisting of several distinguished Members, was delivered to the Admiralty, and in 1832 another Committee was formed with the view of improving the subject. Of the various plans that have been submitted to them, it has been said some are too laborious and complicated for general practice, and others entirely erroneous. Mr. Parsons's Tables seem to form a distinguished feature among these investigations. In a communication made from the Board of Trade to Mr. Lushington, at the time that gentleman was one of the Secretaries of the Treasury, it was urged, that if any new method should augment the tonnage duty, the proprietors should not be subject to additional burthens. It is singular that among the many minds occupied with this useful and important practical question, no one has yet been able to devise a short, accurate, and convenient rule. The object in all these attempts should be, not so much to diminish the present error, as to abolish it entirely. Simplicity is most desirable, but considering the varied forms that ships' bodies put on, it should not be obtained by a sacrifice of principle. We confess we look to the scale of tonnage as one of the great means by which this useful end will be accomplished.*

Seppings's Rules for building and rebuilding Ships of the Line, Fifty-gun Ships on two Decks, and Frigates.

Seppings's rules for building ships of the line, &c.

(422.) Accurate and precise rules for the practical operations of ship-building are of the greatest importance to the successful prosecution of the Art. In vain might the most perfect theories, *did we possess them*, devise forms possessing stability, stowage, and velocity, if, when the fabric is to be reared on the slip, weak and inefficient combinations of timber are to be employed in its formation. A knowledge of scientific carpentry—of the best modes of combining timber, so as to unite a maximum of strength with a minimum of material—is possessed but by very few Naval Architects. Thousands of loads of timber were annually consumed in ship-building, yet, before the time of Seppings, where were the successful instances to be met with of timbers exerting all their power, and disposed according to principles which the eye of Science delights to contemplate? The praise of Seppings is, that he accomplished all this and more for Naval Architecture; and that he imparted to our great and splendid marine a degree of mechanical strength it never possessed before.

Frame agreeably to the common disposition.

(423.) In the common disposition, all the timbers are to be framed together in bends, (except the short timbers over the ports,) each scarf to be bolted with three bolts of $1\frac{1}{8}$ inch diameter for ships of the line, and one inch for 50-gun ships and frigates. The first futtocks also to be bolted to their respective floors, with three bolts in each scarf of $1\frac{1}{4}$ inch diameter for ships of the line, and $1\frac{1}{8}$ inch for 50-gun ships and frigates. The filling frames under the ports to be so opened as to divide the space equally.

(424.) The greatest attention must be paid that the lips of the chocks at the heads and heels of the timbers be at least three inches in thickness, for ships of the line, and not less than $2\frac{1}{2}$ inches for 50-gun ships and frigates, and that the abutments for the lips be cut on the timbers as near to a square as the faying of the chock will admit.

(425.) The chocks are to be roughly trimmed with a sufficiency of overcast, and placed with their faying sides outwards in their respective situations, in which state they are to remain during the seasoning of the frame. Each range of chocks is to be placed on a small fore and aft riband, which is to be kept from coming in contact with the timbers by fitting a piece of

* Since this was written the Committee has published a short Paper on the methods at present in use for measuring tonnage. It may be seen in the *United Service Journal* for June 1834.

batten for every nail to pass through. Such chocks as may be converted from free grown timber, and are therefore liable to split in the course of seasoning, are to have a small treenail driven in a direction from a right angle about nine inches from each end.

(426.) When the chocks are refayed and replaced after seasoning, the faying parts of both chocks and timbers are to be well fayed with oil and tar.

(427.) The heads and heels of the timbers are to be scarfed where so directed on the disposition of the frame, but the heads and heels of all other timbers, where the conversion will admit, are to be wrought square, painted at each end with white lead, and put together with a circular coak in each joint, of a diameter about one-third of the siding of the respective timbers. In the event of the timber being partially shifted so as not to admit of introducing the coak, a bill is to be substituted, which is to be formed on the lower timber to prevent a lodgement of water; such timbers as cannot be procured with square heads and heels are to be scarfed.

(428.) All the timbers are to be framed together in bends, and to be bolted with two bolts in each scarf of $1\frac{1}{8}$ inch diameter for ships of the line, and one inch for 50-gun ships and frigates, and the lower scarfs with bolts of $1\frac{1}{4}$ inch for ships of the line, and $1\frac{1}{8}$ inch for 50-gun ships and frigates.

(429.) The under side of the wing transom to be sided straight and laid at a right angle with the rabbet of the post, and to be sided as much as the piece will admit. If the store will not supply a piece of timber of sufficient dimensions to make the wing transom for a large ship, it may be formed with four pieces. No transoms are to be introduced below the wing transom, but that part of the ship's frame is to be formed with timbers as described in the drawings. Ships built on this principle are to be single fastened throughout.

(430.) That the openings may be kept as clear as possible during the seasoning of the frame, the timbers are to be separated with wedges driven alternately, which are to be taken out as soon as the frames are put together; but in such cases where it may be absolutely necessary to introduce chocks in the usual manner, they are to be split out when the bolts shall have been driven.

Openings between the timbers of the frame to be filled

(431.) The openings between the frames are to be filled in and calked within and without board, from the keel to within four inches of the lower strake under the orlop clamps for ships of the line and 50-gun ships, and to within the same distance of the strake on the ends of the orlop beams in frigates. Care is to be taken that the outer edge of the upper filling lie rather above a level, by which means should any water pass between the timbers, it will be conveyed into the hold of the ship. Openings more than three inches are to be filled in with slab plank free from sap wood, or with sound old oak timber, with the grain in the same direction as that of the frame timbers, which fillings are to be so trimmed as to admit of wedge fillings on one side. Openings less than three inches are to be filled in with wedge fillings, driven in alternately from within and without side, and square with the curve of the body. The filling in is to be executed as the planking of the bottom is carried down, and as the ribands and harpins are removed.

(432.) All the fillings are to be provided as early as possible from offal and slab timber, free from sap, or sound old oak, and when trimmed, are, with the sides of the frame, to be well payed with oil and tar.

Dubbing off the inside of the frame.

(433.) The inside of the ship, below the orlop clamps, need not be dubbed off with that strict attention as if it were to be planked over, but to be made moderately fair, removing the projecting parts so as to prevent the lodgement of dirt.

(434.) The heads of the stem and stern posts and timbers under the ports must be well saturated with oil and tar during the seasoning of the ship, which may be done by making the heads of the timbers concave, and boring holes therein; the holes are to be plugged up, and the timbers cut fair and painted with white lead before the port cills are let in

(435.) Great care is to be taken that no sap be suffered to remain on any part of the frame, and that no piece be put in to make good the deficiency occasioned by its removal from the edges of the timbers until the fillings, &c., shall have been calked.

Calking the frame.

(436.) One joint of the fillings in each opening between the timbers of the frame, and also the joints of the frames in wake of the said fillings, are to be well raimed and calked both within and without board.

(437.) Great care is also to be taken that the oakum which may be driven from one side be brought into close contact with that driven from the other side, so that on no account whatever is any space to be left between the two calkings. When the raiming and calking as already directed shall have been performed, all the remaining joints of the fillings, butts of chocks, butts of timbers, &c. are to be chinced.

(438.) In fig. 1. pl. v. the method of filling in the openings between the timbers, &c. may be seen, and to which the following references may be made. A, a close joint; B, an opening of less than three inches; C, an opening of more than three inches; D, D, D, wedge fillings, the grain being *in* and *out;* E, a common filling, the grain being *up and down;* F, F, F, F, F, F, joints which are to be raimed and calked.

(439.) The fillings in wake of the chain bolts are to be as few as possible, their moulding to be two inches less than the frame, thereby leaving one inch for air to pass between them and the inner and outer planking. They are to be raimed and calked within and without; and should any fillings be required in the wake of the knees, or any other place above the general filling in, the same mode is to be followed.

Projections to be discontinued at the channel wales, bows, &c.

(440.) No projection is to be left at the upper edge of the channel wales, but at the upper and lower edges of the sheer strake projections are to be permitted as usual. No projection whatever is to be allowed without board afore the second lower deck port from forward, and to obviate the additional weight that would arise in consequence, the main wales, &c., are to be thinned at the fore end one-third of their respective thickness, and to begin to taper off about ten feet from the fore end. To render the port lids (where the projections are omitted) as light as they otherwise would have been, the stops are to be cut out of the plank without going home to the port timbers; to accomplish which, the short stuff between the ports must of course be worked fair with the sides of the port timbers.

Coaking the main wales,

(441.) The main wales, black strake, and four upper strakes of diminishing stuff, the middle and channel wales and sheer strakes, are to be coaked to the timbers

of the frame with reference to every butt as described in fig. 2.

Clamps, &c. for ships of the line.

(442.) The clamps and spirketing are also to be coaked to the timbers of the frame in a similar manner to the wales, &c., and the clamps are to be bolted with up and down bolts agreeably to fig. 3.

(443.) Where only one strake of spirketing is wrought, both butts are to be coaked to the timbers nearest their ends.

Coaking the main wales, clamps, &c. for 50-gun ships and frigates.

(444.) The main wales, sheer strakes, spirketing, and clamps, are to be coaked and bolted as directed for ships of the line.

Treenail fastening.

(445.) The timbers of the frame are to be single bored only, in wake of the water way, shelf pieces, and such other parts where fastenings driven for the security of the inside work are generally diffused; also the bottom of the ship where the inside planking is omitted, *viz.* from the lower edge of the plank next under the orlop clamps to the limber strake.

(446.) The general diffusion of metal fastenings introduced with the new system, together with the bolts for bringing to the plank, will more than compensate for the treenails left out.

(447.) Ships built upon the small timber system are to be single fastened throughout.

Orlop clamps for ships of three decks.

(448.) To have two strakes of orlop clamps on each side wrought top and butt, both eight inches thick, with two strakes on each side wrought under them, the upper strake to be six inches thick, and the lower strake four inches thick, which may also be wrought top and butt.

Orlop clamps for 80 and 74-gun ships.

(449.) Two strakes of seven inches thick wrought top and butt, with one of six inches, and one of four inches thick, wrought also top and butt under them.

(450.) Should there be any difficulty in procuring the middle shift of diagonal timbers for ships of the line, another strake (or two if required) of three inches thick, may be wrought in *midships* below the strake of four inches. Care is to be taken that it be not worked so low as not to give a five feet scarf to the middle rider from the upper part of the longitudinal piece at the first futtock heads.

Orlop clamps for 50-gun ships.

(451.) Two strakes of six inches thick, wrought top and butt, and one strake of four inches thick wrought under them.

Hold. Limber strake for ships of the line and 50-gun ships.

(452.) No plank or thick stuff whatever is to be wrought below the said strakes except one limber strake on each side, eight inches thick for ships of three decks, seven inches thick for 80 and 74-gun ships, and six inches thick for 50-gun ships, and to be coaked to the cross chocks only, with circular coaks, of 4½ inches diameter.

Limber strake for frigates.

(453.) No plank or thick stuff is to be wrought in this class of ships below the strake on the ends of the orlop beams, except one limber strake on each side of six inches thickness, which is to be coaked to the cross chocks only, with circular coaks of four inches diameter.

Additional keelson.

(454.) In the wake of the main mast an additional keelson is to be placed on each side, at such a distance from the common keelson that the ends of the step may rest upon it, to support the great pressure of that mast. The additional and regular keelsons to be coaked to the cross chocks only, instead of being faced down as heretofore.

(455.) To be of the same dimensions as the common keelson, and in length for ships of the line about twenty-eight feet, and for 50-gun ships and frigates about twenty-four feet.

Trussed frame.

(456.) Instead of thick stuff, plank, riders, &c., a trussed frame is to be introduced, the various parts of which (particularly the longitudinal pieces and trusses) are to be procured if possible from old ship timber, *viz.* the sound parts of old floors, first futtocks, &c. Should any sound old timber in a very dry state be made use of, it should be saturated with oil and painted with white lead to prevent an absorption of moisture.

Trussed frame for ships of the line.

(457.) The diagonal timbers for ships of three decks, the upper and lower ones to be fourteen inches sided in midships, and the middle ones fifteen inches; and for two-decked ships the upper and lower ones to be from thirteen to fourteen inches, but the middle ones are not to be less than fourteen inches sided. The fore and aft pieces at the floor heads are to be sided in midships from thirteen to fourteen inches as the conversion will admit, and afore and abaft from twelve to thirteen inches; the fore and aft pieces at the first futtock heads from eleven to twelve inches, the small dimensions to be used forward and aft.

(458.) The trusses to be sided from eleven to twelve inches, and with the fore and aft pieces to be moulded so as to conform to the diagonal timbers as nearly as the conversion will admit.

(459.) In executing the trussed frame the middle timber is to be first got into its station, and laid as nearly to a right angle from the body of the ship as possible; the upper part to abut against the fore and aft stuff that runs under the orlop clamps, and the lower part to be continued two feet six inches below the floor heads, or as much more as the piece will admit. The lower timber may next be placed, which is to abut against the limber strake, and to run at least two feet six inches above the floor heads, thereby giving a scarf of not less than five feet to the middle timber: and in order to take out the bevelling, or in other words to make the timber lie nearer at a right angle to the body, the lower end of the middle timber is to be reduced at the upper part, where it comes in contact with the lower timber. In the fore body it will be taken from the aft side, and in the after body on the fore side; the lower part of the upper timber, or upper part of the middle timber, is also to be taken away for the same purpose.

(460.) Should any difficulty occur in procuring compass timber for the diagonal frame, a saw kerf may be cut in the upper part of the upper, and in the lower part of the lower timber, thereby avoiding a kerf in wake of the scarf. This will render procuring these timbers less difficult.

(461.) In disposing of the diagonal timbers so as to clear as much as possible the chocks under the gun deck shelf piece, a chamfer of about six inches may be taken away when required from the angle of the lower edge of the orlop beam, as in fig. 4.

(462.) The scarfing of the diagonal timbers to be side by side, and each of the lower scarfs to be secured with two copper bolts of 1¼ inch diameter, and each of the upper scarfs with two copper bolts of 1⅛ inch diameter, which are to be driven square from the sides of the timbers.

(463.) Each shift or diagonal timber to be coaked to the frame timbers, and to the gun deck and orlop clamps with which they come in contact, with coaks of 3½ inches diameter, and 3½ inches in length.

(464.) The fore and aft pieces at the floor and first

futtock heads are to have their ends coaked to the diagonal timbers with coaks of four inches diameter, and of the same length. As these coaks must be double sunk either in the timber, or in the fore and aft pieces to ensure their being driven up, a piece of thin iron hoop is to be placed over one end of the coak to prevent its being split by the bolt in punching up; this precaution should be taken in all cases where coaks are double sunk.

(465.) Wherever there is a necessity of double sinking coaks, the vacant space is invariably and with the greatest care to be filled with a mixture of chalk and grease, or any other durable substance that can be introduced.

(466.) Great attention should be paid that the fore and aft pieces at the floor and first futtock heads be driven in tight between the diagonal timbers, and particularly the trusses, as they receive the weight of the ship when she has a tendency to arch or hog, and also when in the act of pitching.

(467.) As the trusses need not have any coaks at their ends, should they by accident be cut short, an iron wedge is to be driven at one end; and should they have shrunk, particularly at the upper ends, after they are put in place, thin iron plate wedges are to be driven in prior to the ship's being launched or undocked. In all cases a survey should be held to ascertain their state before the ships be launched or undocked.

(468.) The diagonal timbers are to be bolted with bolts of 1¼ inch diameter, the bolts to be from eighteen to twenty inches apart, except at the extreme ends, where two may be placed nearly abreast; and at the heads of those under the gun deck shelf piece, two bolts are to be driven through a plate of iron to secure them when the ship is in the act of rolling.

(469.) The fore and aft pieces at the floor and first futtock heads to be fastened at their ends with bolts of 1¼ inch diameter, and in the middle with bolts of 1⅛ inch diameter, and from twenty inches to two feet asunder, the ends excepted, where, as in the ends of the diagonal timbers, they are to be nearly abreast.

(470.) The trusses are to be secured with bolts of 1⅛ inch diameter, about two feet asunder. The upper trusses to be placed a little above a square or 90°.

(471.) In driving the bolts of the diagonal frame, all those in the ends, and one at least in the middle, are to be driven first, and from the inside, in order to draw the materials well in contact with the frame timbers.

(472.) Water courses are to be cut wherever there is a probability that water may lodge, particularly at the ends of the fore and aft pieces and trusses, also at the ends of the diagonal timbers that abut against the limber strake, and the keelsons in wake of the main mast; these water courses are to be formed by cutting off the angle with a plain chamfer at the upper part about four inches, and at the lower part five inches, the same to be observed with respect to the hooks, crutches, &c., but to a greater extent.

Trussed frame for 50-gun ships and frigates.

(473.) The materials for the diagonal frames of these classes of ships to be six inches thick. The timbers and fore and aft pieces to be from ten to eleven inches broad, and the trusses from nine to ten inches broad.

(474.) The upper range of timbers may be procured of small timber, sided eleven inches for 50-gun ships, and ten inches for frigates; the upper parts of which must be fayed to the clamps, &c., but the lower parts may be brought to with boiling in the kiln, should there be any difficulty of procuring timber of a proper growth.

(475.) Chocks of dry oak well oiled are to be wrought under the lower edge of the lower strake of inside stuff to prevent the scoring of the diagonal timber.

(476.) The other parts of the diagonal frame may be procured of thick stuff, and brought to with boiling, (should it be required,) excepting those parts afore and abaft to form the hooks and crutches, which may be converted from small timber sided from ten to eleven inches, and moulded as broad at the middle line as may be required to receive the iron plate hooks or crutches.

(477.) The bolts for the diagonal timbers to be in distance asunder from eighteen to twenty inches, except at the ends, where two are to be disposed of, as before directed for ships of the line; those for the upper range of timbers, and for the parts which form the hooks and crutches, are to be 1⅛ inch diameter, and the remainder one inch diameter.

(478.) Whenever the treenails of the bottom come in wake of, and at a *proper distance* from the edges of the fore and aft pieces and trusses, they are to pass through them; and the additional fastenings that may be required are to be made with bolts of ⅞ diameter; the ends are also to be secured with two bolts in each, as directed for ships of the line.

(479.) Water courses are to be formed by cutting off the lower angle of those parts of the diagonal frame which form the breast hooks and crutches; but *no water courses* are to be cut in any other part of the diagonal frame.

(480.) The greatest care is to be taken that the fore and aft pieces and trusses be driven in tight between the timbers, and that their butts be well compressed by raiming prior to their being calked. The upper trusses shall be placed a little above a square or 90°.

(481.) The hooks and crutches are to be constructed on a principle that will be shown by a drawing. Hooks and crutches.

	Line of Battle Ships. Cwt.	qr.	lbs.	Frigates. Cwt.	qr.	lbs.
Weight	5	1	14	4	1	7

(482.) The fore and aft carling under the after gun-deck beams, is to be secured to the inner post, and is to run to the beam afore the mizen step. Fore and aft carling under after lower deck beams.

(483.) The orlop beams for ships of the line to have a fore and aft strake of four inches thick placed under them in the midships, to receive the heads of the pillars in the hold. Strake under orlop beams.

(484.) The half beams are all to be of fir, except those in the cable tiers. Half beams.

Scantlings.

	Ships of the Line, 3 Decks.	Ships of the Line, 2 Decks.	50-gun Ships.	Frigates.
Orlop	Sq. 11	Sq. 10½	Sq. 10	Sq. 8
Lower deck	11	10½	10	8
Middle deck....	10			
Upper deck	9	9	8½	9½
Quarter deck and forecastle ...	7	7	7	7
Roundhouse ...	5½	5½	5	

A piece of oak plank is to be brought on the end of each half beam to make it of sufficient depth to reach the shelf piece.

The midship end of each half beam is to be secured to the carling with a dog-bolt.

Carlings under the midship ends of the diagonal flat for ships of the line. Diagonal ledges. Shelf pieces.

	Br. In.		Dep. In.
(485.) For the gun deck	12	..	10
For middle and upper decks	11	..	9
To be of old oak, thick stuff, or plank.			
For the gun deck about	10	..	5
For middle and upper decks	9	..	4

	Ships of the Line.		50-gun Ships.		Frigates.	
	Inches thick.	Inches broad	Inches thick.	Inches broad.	Inches thick.	Inches broad.
For the orlop .	9	15	8	14	11	11
	To be in	a direc	tion as	shown	by a dra	wing.
Lower deck ..	9	15	8	14	7	12
Middle deck ..	8	14				
Upper deck ..	8	14	7½	13	8	14
Quarter deck and forecastle....	7	12	6½	11	6½	11
Roundhouse ..	6	10	5½	10		

The breadth given is for the upper side of the shelf piece, the front side being bevelled.

(486.) The scarfs to be five feet six inches long, and to be coaked with four circular coaks in each scarf; the scarfs to be so disposed that the front lip may overrun a chock under the shelf piece about four inches.

(487.) Should any difficulty occur in procuring shelf pieces on account of breadth, they may be wrought by bringing the top ends together alternately, and introducing a connecting shift as described in fig. 5.

(488.) The shelf pieces are to be secured with bolts from eighteen to twenty inches asunder, and as the throat bolts of the iron knees will pass through the shelf pieces, no bolt should be placed nearer than twelve inches to the midde of each chock that is intended to receive an iron knee.

(489.) The diameter of the in and out, and up and down bolts for shelf pieces must be as follows:

	Ships of the Line.	50-gun Ships.	Frigates.
Orlop..................	1¼	1¼	1
Lower deck	1¼	1⅛	1
Middle deck............	1⅛		
Upper deck	1⅛	1⅛	1⅛
Quarter deck and forecastle.	1	1	⅞
Roundhouse	⅞	⅞	

Coaks for shelf pieces.

(490.) The diameter of the coaks for the shelf pieces, and the number in each beam end, are to be as follows:

		Ships of the Line.		50-gun Ships.		Frigates.	
		In.	No.	In.	No.	In.	No.
Each beam end and shelf piece.	Orlop..................	4	2	3½	2	4½	1
	Lower deck.............	4½	2	4	2	4½	1
	Middle deck	4	2				
	Upper deck	4	2	3½	2	4	2
	Forecastle and quarter deck	4½	1	4	1	4	1
	Roundhouse	4	1	3½	1		
[Each h]alf beam [an]d shelf [pi]ece.	Orlop	4½	1	4	1	3	1
	Lower deck............	4½	1	4	1		
	Middle deck	4	1				
	Upper deck	4	1	3½	1	3½	1
	Forecastle and quarter deck	4	1	3½	1	3	1

(491.) These coaks are to be of cast iron 4 inches long, and the cavity to be filled with cement and sand; if iron coaks cannot be procured, hard seasoned durable wood coaks are to be substituted.

Chocks for iron knees.

(492.) The chocks under the shelf pieces or beams for iron knees, are to be sided as follows:

	Ships of the Line.	50-gun Ships.	Frigates.
	Inches.	Inches.	Inches.
For the Lower deck	10	9	7
Middle deck.......	9		
Upper deck.......	8½	8	8
Quarter deck and forecastle	7½	7	7
Roundhouse	6	5½	

(493.) The chocks under the orlop shelf pieces are to be placed conformably to directions that will be given with a section, sided for ships of the line and 50-gun ships from eleven to twelve inches, and for frigates from ten to eleven inches. Care is to be taken that the bolts for the diagonal timber in the wake of these chocks, be so disposed as to pass through the chocks.

(494.) The beams of the gun deck, and also those of the orlop, to be stationed so as to receive a side plate, by keeping one side of the chock fair, or in such a direction with the fore or after part of the beam as may be most convenient.

(495.) Side plates for ships of the line five inches broad, 1⅝ inch thick; for 50-gun ships, 4½ inches broad, and 1¼ inch thick, diameter of the bolts 1¼ inch.

(496.) The chocks under the midship lower deck beams of frigates, are to abut on the beam ends of the midship platform in the same manner as those of ships of the line, and 50-gun ships do on the orlop beams, but no side plates are required for frigates.

(497.) The chocks under the shelf pieces are to be got into place as tight as possible, which may be accomplished by previously setting the beams an inch above their proper round.

Forked knees.

(498.) The weights of the forked knees are to be as follows:

	Ships of the Line.	50-gun Ships.	Frigates.
For the Lower deck......	about 3½ cwt.	3	
Middle deck	2¾		
Upper deck......	2¼	2¼	2¼
Quarter deck and Forecastle ...	1½		

(499.) Those beams that are placed over ports where the forked knee cannot with convenience be introduced, are to be secured by iron dagger knees on chocks, with an ear against the side for the introduction of a bolt.

(500.) The diameters of the bolts for the forked knees are to be as follows, *viz.*

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		Inches.
Lower deck.	The two throat bolts and the up and down bolt	$1\frac{3}{8}$
	The lower bolts and those fore and aft in beams.	$1\frac{1}{4}$
Upper and middle decks.	The throat, and up and down bolts.	$1\frac{1}{4}$
	Bolts below, and the fore and aft ditto	$1\frac{1}{8}$
Quarter deck and fore-castle.	The two throat bolts, and the up and down ditto.	$1\frac{1}{8}$
	Bolts below, and fore and aft ditto	1

The up and down bolts in the lower, upper, and quarter decks, are to be of copper.

Iron knees under beams.

(501.) The lower deck beams of frigates, and the forecastle and quarter deck beams of 50-gun ships and frigates, to be secured at each end with an iron knee under the beam, in weight $1\frac{1}{2}$ hundred weight, the toes or ends to be $\frac{1}{2}$ inch in thickness and bolted with bolts of one inch diameter.

Round house beams to be secured with plate bolts.

(502.) The beams of the round house are to be secured with a plate bolt at each end, diameter of the bolt in the beam $1\frac{1}{4}$ inch, and bolted with bolts of $\frac{7}{8}$ inch diameter. The plate on which the bolt is clenched is to lie upon the beam and be let into the under side of the flat of the deck.

Beam ends to be secured with bolts driven through the bottom.

(503.) The beams of the orlop and platforms, and the foremost and aftermost beams of the lower decks of frigates, are to be secured with three bolts of $1\frac{1}{8}$ inch in each end, which are to be driven through the bottom of the ship.

Trussing between the ports of ships of the line, 50-gun ships, and frigates.

(504.) The short stuff, or quick work between the ports of the lower, middle, and upper decks, to be composed of materials, sound, well seasoned, and converted from old timber if it can be procured. The abutment pieces for the gun deck to be about thirteen inches broad, and for the middle and upper decks twelve inches.

(505.) The trusses for the gun deck to be eleven inches, and for the middle and upper decks ten inches broad. The abutment pieces are to be the same thickness as the clamps, if they do not exceed six inches, which are not to be bearded, but should they exceed that thickness, they are to be bearded to six inches; but the diagonal trusses are to be half an inch less in thickness.

(506.) Every abutment piece is to be coaked to the port timber, with one circular coak of $3\frac{1}{2}$ inches diameter, which is to be placed so as to act against the pressure of the truss on the abutment piece. The head of each abutment piece is to be bolted with two in and out bolts of $\frac{7}{8}$ inch diameter, each end being also bolted in a fore and aft direction, with one bolt of the like diameter. The space between the trusses and abutment pieces is to be left open, while the ship is in a state of ordinary, but when commissioned it is to be coppered over.

(507.) In calking the trusses between the ports, the horizontal parts in contact with the spirketing and clamp are to be well raimed and calked, by which means they will act well against the up and down, or abutment pieces; but should there be a space left between the abutment pieces and trusses more than the calking will set home, the up and down joint is to be first calked, or a neat iron plate is to be driven in.

Trussing the stern.

(508.) Whether the stern be built in the common principle, or round with the rother head without board, drawings will be sent. The lower, middle, and upper decks of ships of the line, are to be laid diagonally.

(509.) The water ways for the lower deck to be from thirteen to fourteen inches square, and for the middle and upper decks from $12\frac{1}{2}$ to thirteen inches square. These scantlings may be easily procured, as the rabbet and rounding of the front will materially assist the conversion. The rabbet for the flat of the deck is to be taken out, so as to admit of a calking seam of three inches in depth, and with such an angle that the butts of the flat of the deck may be bearded $\frac{3}{8}$ inch and *no more.*

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Water ways for diagonal decks.

(510.) To prevent a lodgement of water on the upper side of the water ways, they are to be trimmed below a level from the spirketing, inwards, which may be done by letting the water ways down more on the inner edge, than on that next the timbers, according to fig. 6.

(511.) It being of the greatest importance that the water ways and ekeings be procured of dry, well seasoned oak, or timber of equal durability, great care is to be taken in the selection; and to promote this object, the water ways may be wrought of short lengths and butted on carlings let down for that purpose between the beams, observing that no more carlings are to be introduced than may be necessary for this purpose, and that they be let down in scores which are to be taken entirely from the half beams.

(512.) The carlings are to be of the same breadth as the water ways, and in depth the same as the binding strake, the upper sides of the carlings being flush with the upper sides of the beams. The clamps and spirketing are to be worked according to the usual practice.

(513.) The butts of the water ways are to be disposed of in the middle of the carlings, and the scoring down part of the water way to be taken away from the butt to the side of the beam next to it, as shown in fig. 7, and the binding strakes are to give shift to the water ways.

(514.) Each butt of the water ways is to be secured to the carling with two coaks, and one up and down bolt. The bolt is to pass through the shelf piece, but should the bolt that passes through the end of the half beam come near to the butt of the water way, then one up and down bolt may be omitted. The in and out bolts in the wake of these carlings will necessarily pass through them instead of the water ways.

(515.) No ekeings are to be wrought of greater scantlings than may be necessary to get the water ways in and out of place, and to admit of disposing the up and down bolts so as to clear the rabbet of the water way, the spirketing, and the clamps sufficient for clenching. The ekeings are to give shift to the water ways, and thereby reduce the calking at the butts as well as give a stop to the same.

(516.) The water ways and ekeings are to be scored down on the gun deck main or principal beams three inches, and on the middle and upper deck main or principal beams $2\frac{1}{2}$ inches; the scores are to be taken from the water ways and ekeings, and the butts faced on the sides of the beams $\frac{1}{2}$ an inch. No scores are to be taken from the water ways and ekeings in wake of the half beams, but the scores are to be taken from the half beams entirely.

(517.) One up and down bolt in the water ways through the shelf piece is to be disposed of in the end of each beam and half beam, the diameter of the bolts for the beams of the gun deck to be $1\frac{1}{4}$ inch, and for the middle and upper decks $1\frac{1}{8}$ inch, for the half beams of the gun deck $1\frac{1}{8}$ inch, and for the middle and upper decks one inch.

(518.) The in and out bolts in the upper part of the water ways are to be equal in number to those in the lower part in the binding strakes; the diameter of the bolts for the gun deck to be $1\frac{1}{8}$ inch, and for the middle and upper decks, one inch.

(519.) The diameter of the coaks for the water ways and the number in each beam end to be as follows, *viz.*

Coaks for water ways.

		Inches.	No.
Each beam end water way.	Lower deck	4	2
	Middle and Upper decks..	$3\frac{1}{2}$	2

These coaks are to be of cast iron four inches in length; if iron coaks cannot be provided, then well-seasoned, hard, durable wood is to be substituted.

Side binding or scoring down strakes for securing the ends of the flat of diagonal decks for ships of the line.

(520.) Thick strakes for the gun deck six inches, and for the middle and upper decks five inches, broad ten inches, to be let down in scores taken from the *main* or principal beams; for the gun deck three inches, and for the middle and upper decks $2\frac{1}{2}$ inches; and what may be required to make the upper side of the binding strake flush with the upper sides of the beams, is to be taken from the binding strake, and the scores are to be faced on the sides of the beams half an inch. No scores are to be taken from the binding strakes for half beams, but the scores are to be taken from the half beams entirely.

(521.) One in and out bolt in the binding strake and lower edge of the water way, is to be disposed of in the space between each beam and half beam; and as there will be a space of three inches between the binding strake and water way, no chocks are to be fitted for the purpose of wooding the bolts. The diameter of the bolts for the gun deck to be $1\frac{1}{8}$ inch, and for the middle and upper decks one inch.

Midship binding strakes for the gun, middle, and upper decks of ships of the line, 50-gun ships, and frigates.

(522.) The binding strakes in midships are to be coaked to every main beam and breast hook, with one circular coak of $3\frac{1}{2}$ inches diameter. To be five inches thick from the aft part of the fore hatchway forward for the gun decks of ships of the line, and four inches thick from the ward room or cabin bulk heads forward for middle and upper decks.

Diagonal decks for the gun, middle, and upper decks of ships of the line.

(523.) Every side butt of the flat is to be fastened to the side binding or scored down strake, with two treenails of $1\frac{1}{2}$ inch diameter, except in those beams where the up and down bolts in the forked knees, or the bolts directed for the half beams pass through the flat, then one treenail only is to be driven; the holes for which are not to be bored until the deck shall have been calked, but not payed. All these treenails are to pass through the binding strake, but only one treenail is to pass through each half beam; those in the gun deck main beams being ten inches long, and in the middle and upper deck main beams nine inches long.

(524.) Every midship butt is to be fastened to the main beams, or carlings, as the case may be, with two bolts, and every plank to be bolted with two bolts in each beam, which it may cross; the bolts are all to be $\frac{5}{8}$ of an inch diameter, and eleven inches long, for the gun deck, and eight inches long for the middle and upper decks; the holes are to be bored through the beams, to admit of driving out the bolts. To be fastened to the half beams with two, and to the ledges with one deck treenail.

(525.) One up and down bolt is to pass through the flat of the deck, the side binding or scored down strake, and each main and half beam, excepting those beams of the upper and middle decks, where a knee bolt passes through the binding strake: at the gun deck these bolts will pass through the shelf piece; diameter of the bolts for the gun deck one inch, and for the middle and upper decks $\frac{7}{8}$ of an inch.

Calking diagonal decks.

(526.) The calking of diagonal decks to be carried on progressively, as follows:

1. The treenails.
2. The fore and aft seam, next the binding strake in midships.
3. The diagonal seams.
4. The water way seam.

Care is to be taken that the diagonal seams under the water ways be well filled with oakum, for which purpose irons are to be used similar to those described for that purpose in fig. 8.

Inner or coaked water ways for fore and aft decks.

(527.) The forecastle, quarter deck, and round house of ships of the line, and all the decks of other ships and vessels, to be laid in a fore and aft direction. The coaked water ways for lower decks of 50-gun ships, to be $12\frac{1}{2}$ inches square, and for frigates $10\frac{1}{2}$ inches; for the upper decks of 50-gun ships and frigates, $11\frac{1}{2}$ inches square; for the forecastle and quarter deck of ships of the line, 50-gun ships and frigates, $10\frac{1}{2}$ inches, and for the round house of all ships, to be nine inches square.

(528.) The rabbet to be taken out of the coaked water way, so as to admit of a calking seam of three inches in depth, and with such an angle, that the thin water way may be bearded $\frac{3}{8}$ of an inch, and no more.

(529.) The coaked water ways to be bolted with one up and down bolt in each beam and half beam; the diameter of the bolts for the main beams of the lower decks of 50-gun ships to be $1\frac{1}{4}$ inch, for the upper decks of 50-gun ships and frigates $1\frac{1}{8}$ inch; for the lower decks of frigates, and the forecastle and quarter deck of ships of the line, 50-gun ships, and frigates, one inch, and for the round house of all ships $\frac{7}{8}$ of an inch.

(530.) The diameter of the up and down bolts in the water ways and half beams, to be $\frac{1}{8}$ of an inch less than has been directed for the main beams.

(531.) The in and out bolts for the water ways, to be disposed of at the distance of from twenty inches to two feet asunder, and to be in diameter as directed for the up and down bolts of the respective main beams. This kind of water ways to be butted on carlings, as already described for the diagonal decks.

Coaks for water ways for fore and aft decks.

(532.) Each main beam end and water way to be coaked with circular coaks of cast iron of the following diameters and number.

	Ships of the Line.		50-gun Ships.		Frigates.	
	In.	No.	In.	No.	In.	No.
Lower deck	..		4	2	$3\frac{1}{2}$	1
Upper deck	..		$3\frac{1}{2}$	2	$3\frac{1}{2}$	2
Forecastle and quarter deck	4	1	4	1	4	1
Round house..........	$3\frac{1}{2}$	1	$3\frac{1}{2}$	1		

Outer or thin water way for fore and aft decks.

(533.) The outer water ways to be one inch thicker than the flat of the respective decks, and to be fastened to the beams and half beams with treenails, and the butts to be secured with mixed metal nails.

Forecastle, waist, and quarter deck.

(534.) The forecastle, waist, and quarter deck of ships of the line, 50-gun ships, and frigates, are to be fastened with mixed metal nails.

Bolts for the flat of decks

(535.) The holes for the bolts of diagonal decks are to be bored through the beams to admit of driving out

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the bolts on a repair; the bolts are to be made with tool heads, and the points to be rounded for the purpose of driving them out with concave punches.

(536.) In the event of shifting the decks, the holes are to be bored through the new deck, by introducing the auger into the original holes in the beams from the under sides; and to prevent the necessity of re-fastening the bolts of a larger diameter than were originally driven, a rope-yarn or yarns is to be introduced in each hole of sufficient length above the deck to take a turn round the head of the bolt before it may be driven home. But should this mode be found objectionable in practice, either the original mode may be followed by driving bolts of a larger diameter, or the old holes may be plugged up and new ones bored.

Cross bolting of the wood ends forward and aft when transoms are omitted.

(537.) A system of cross bolting is to be introduced between the bolts of the knee of the head and hooks from the orlop upwards, two bolts of $1\frac{3}{8}$ inch diameter for ships of the line, and two bolts of $1\frac{1}{4}$ inch for 50-gun ships and frigates, to be disposed of in each space between the hooks agreeably to fig. 9. No sap wood (except on elm) is to be suffered to remain in any part of the ship, but it is to be taken off from the materials before they are placed in the ship. The officers are to be considered particularly responsible for the performance of this duty.

Sap wood to be taken away.

Circular coaks and holes for ditto painted.

(538.) The holes for circular coaks are invariably to be painted with white lead. Wooden coaks are to be made of the soundest and best seasoned durable wood that can be procured, they are to be soaked in oil, and their ends painted with white lead. In all cases great care is to be taken that the holes are not sunk lower than the coaks themselves, and where double sunk coaks are used great care is to be taken to fill up the space with chalk and grease as before directed.

Oil and tar.

(539.) In all cases where oil and tar have been directed to be used, the mixture is invariably to be made with four-fifths of oil and one-fifth of tar.

Copper bolts for iron knees.

(540.) Every copper bolt for iron knees, is to be driven with a ring under its head, and those copper bolts which are clenched upon the bottom under the line of flotation, are to be carefully chinced, and putty placed upon the oakum before the ring is put on.

Beams to be placed erect for seasoning.

(541.) In order to facilitate the seasoning of beams they are to be converted as early as possible, and placed as near the ship as convenient, with their butt-ends upwards; and as oil has been found to be a great preventive to the dry rot, the butt-ends of these important parts of the ship are to be hollowed out so as to retain a quantity of oil, by which means it will be most readily absorbed by the timber; a fresh supply of oil is to be afforded occasionally, and, in trimming the beams, as little of their ends so saturated, is to be cut off as possible. The ends of the beams are to be covered, so as to protect them from water, and admit a free circulation of air.

Means to be taken for the preservation of the materials.

(542.) Defects are to be cut out of timbers of the frame, and all other parts of the ship, before they are stowed away for seasoning; and those timbers where defects have been removed, the hole is to be on the under side, but if that cannot be done, a hole is to be bored to take off the water.

(543.) The faying part of the various materials, *viz.* diagonal timbers, fore and aft pieces, trusses, hooks, crutches, chocks under beams, the water ways and ekeings to ditto are to be charred with shavings or ironed with a hot iron, and while hot to be payed with oil and tar.

(544.) All the timbers of the frame in the hold of the ship, but particularly those under the magazine and coal-hole, *when perfectly dry*, are also to be payed over with oil and tar twice or more during the time the ship is building. The rents and shakes of the frames, and also the diagonal framing, are to be chinced, and the surface well payed with oil and tar.

(545.) The ends of beams, longitudinal pieces, trusses, chocks, under-shelf pieces, carlings, &c. after being well saturated with oil and tar, are to be painted with white lead. By this process the capillary tubes will be prevented from absorbing the juices of the timber with which they are to be brought in contact.

Openings, &c. to be kept clear of chips, &c.

(546.) The strictest attention is to be paid during the building of the ship, to keep the openings of the frame and every other part clear from chips or dirt, or any thing that may obstruct a free circulation of air.

Entrances to hold.

(547.) An entrance to the hold is to be left open in all ships at the head, and also on one side in midships as long as the carrying on of the works will admit, not only for the convenience of conveying the materials on board, but to facilitate the seasoning of the ship by creating a circulation of air; which latter object will be further promoted by leaving open the treenail holes in various parts until the calking of the ship. The calking of the ship is not to be performed until it shall be considered necessary. A strake is to be left open on the outside, opposite to the opening above the strake on the orlop beams within board.

(548.) When a ship is not built or repaired under a roof, every possible precaution is to be taken to keep her dry during the progress of the works; and to accomplish this desirable object, the forecastle, quarter deck, and round house are to be laid and calked as early as possible, and a temporary housing erected over the waist. Eave boards are also to be fitted to the topside, as already practised, to carry the water from the ship. If necessity should compel the use of unseasoned timbers, it is to be boiled in the kilns, and afterwards exposed to the air as long as possible.

(549.) Fig. 1, 2, and 3, pl. vi. represent the sheer plan or elevation, the body plan or plan of projection, and the half-breadth plan of a first-rate of 120 guns.

Commercial marine of Great Britain.

(550.) Great Britain is not only deeply interested in all that concerns her Navy, but also in that commercial marine, which connects her with other nations. When we look at the magnitude of this portion of her power, at once the ample feeder of her wealth, and a nursery of seamen for all the daring enterprises of war, we cannot but regard every improvement by which additional security can be imparted to it, with the greatest interest and delight. By the modes of ship-building commonly practised in our merchants' yards, Sir Robert Seppings observes there can be little doubt that lives and property to an immense amount must from time to time be sacrificed by injudicious modes of construction, and by the inefficient plans which have had no better origin than a rude and barbarous experience.

Its importance.

(551.) An idea of the great importance of our commercial marine may be gathered from the following statement of the British shipping employed in the trade of the United Kingdom, and which have actually entered the several Ports of Great Britain for some preceding years.

Commercial shipping for 1831

	1826	1827	1828	1829	1830
British Tonnage	1,796,250	1 972,790	1,955,548	2,033,854	2,036,091

(552.) For the year 1831 we present a more detailed

list of the shipping employed in the trade of the United Kingdom, together with the number and tonnage of vessels entered inwards and cleared outwards, (including their repeated voyages,) with the number of their crews; separating British from Foreign ships, and distinguishing the trade with each Country.*

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Countries, &c.	Inwards.						Outwards.					
	British.			Foreign.			British.			Foreign.		
	Ships.	Tons.	Men.	Ships.	Tons.	Men.	Ships.	Tons.	Men.	Ships.	Tons.	Men.
Russia	2,065	394,850	18,246	132	33,867	1,677	1,605	316,361	14,654	129	32,827	1,488
Sweden	84	11,450	616	195	38,689	1,896	67	8,953	528	118	21,782	1,079
Norway	52	4,518	306	754	114,865	6,145	33	2,876	194	784	128,480	6,610
Denmark	66	6,552	329	748	62,190	3,672	437	70,324	3,450	925	102,639	5,474
Prussia	487	83,908	3,873	701	140,532	6,084	303	50,792	2,394	395	80,852	3,483
Germany	724	109,651	5,579	632	58 411	3,138	665	102,026	5,194	589	49,635	2,688
United Netherlands	1,723	187,456	10,528	756	82,449	4.492	1,617	179,488	9,740	784	86,461	4,931
France	1,312	97,057	9,450	1,254	73,159	7,747	1,191	90,311	9,146	975	62,530	5,770
Portugal, *viz.* Proper	401	43,168	2,537	54	6,084	495	381	43,574	2,673	132	21,243	1,251
Azores	220	17,454	1,086	9	817	74	177	12,750	889	6	510	51
Madeira	11	1,402	96	...	....	....	8	1,102	72			
Spain and the Balearic Islands	686	73,627	4,173	87	8,800	671	520	58,014	3,424	96	14,239	895
Canary Islands	45	5,284	281	...	....	....	43	5,259	307			
Gibraltar	8	953	50	...	....	....	106	14,349	807	4	723	44
Italy and the Italian Islands	497	75,875	4,132	97	19,712	1,275	383	54,837	3,089	71	14,502	912
Malta	27	4,509	249	...	....	....	61	10,561	555	3	736	45
Ionian Islands	60	8,482	473	...	....	....	35	5,306	288	1	224	16
Turkey and Continental Greece	129	18,180	1,020	...	....	....	117	17,696	1,015	2	407	21
Morea and Greek Islands	13	1,822	98	...	....	....	3	375	21			
Egypt (Ports on the Mediterranean.)	35	8,417	401	...	235	9	39	8,178	413	2	396	28
Tripoli, Barbary, and Morocco	12	1,178	63	...	....	....	3	330	19			
Coast of Africa, from Morocco to the Cape of Good Hope	126	36,710	1,852	...	....	....	116	31,849	1,889			
Cape of Good Hope	27	4,626	260	...	....	....	37	7,213	423			
Eastern Coast from the Cape of Good Hope to Babelmandel	1	134	13									
Cape de Verd Islands	....	....	....	...	....	....	2	468	27	3	688	33
St Helena and Ascension	....	....	....	...	....	....	6	1,164	71			
Mauritius	69	19,315	1,028	...	....	....	28	8,067	452			
East India Company's Territories and Ceylon	150	63,566	4,217	...	....	....	137	59,721	4,187			
China	21	27,889	2,783	...	....	....	22	28,081	2,764	3	1,126	58
Java	2	883	53	...	....	....	12	3,505	197	4	1,287	63
Philippine Islands	7	2,078	118									
Other Islands of the Indian Seas	....	....	....	...	....	....	4	1,085	111			
New South Wales	35	11,875	675	...	....	....	78	27,623	1,867			
New Zealand and South Sea Islands	1	537	43	...	....	....	4	1,359	110			
British Northern Colonies	1,758	480,236	22,276	...	....	....	1,804	473,338	23,257	1	522	20
British West Indies	904	249,079	13,691	...	....	....	907	249,051	14,108			
Hayti	25	4,633	256	2	321	17	43	7,518	450			
Cuba and other Foreign West Indies	35	7,438	377	8	2,065	88	78	14,927	873	14	3,718	179
United States	289	91,787	4,204	639	229,869	9,807	358	114,200	5,406	651	231,280	10,209
Mexico	32	4,971	295	5	668	48	30	5,056	293	4	639	39
Guatemala	1	206	9	...	....	....	.1	174	10			
Colombia	8	1,707	91	...	....	....	15	2,937	163			
Brazil	216	49,414	2,521	5	965	70	239	58,681	2,974	3	618	34
States of the Rio de la Plata	42	7,829	426	...	....	....	25	4,483	255	1	163	8
Chili	5	982	58	...	....	....	18	3,602	231			
Peru	11	1,920	112	...	....	....	7	1,291	78			
The Whale Fisheries	111	37,454	4,415	...	....	....	110	36,472	4.828			
Islands of Guernsey, Jersey, Alderney, and Man	1,955	106,230	8,268	6	907	48	1,867	97,465	7,749			
Foreign Parts, the particular Places cannot be specified)	....	....	....	...	....	....	49	7,939	359	227	37,824	1,580
Total	14,488	2,367,322	131,627	6,085	874,605	47,453	13,791	2,300,731	132,004	5,927	896,051	47,009

Imperfect mode by which merchant ships are at present constructed

(553.) With regard to the principle on which mercantile ships are at present constructed, and particularly as regards the putting together their ribs or frames, and the arrangement of the materials, it may be observed, that in forming the frames or ribs, half of the timbers only are united so as to constitute any part of an arch, the alternate couples only being connected together; the intermediate timbers (termed fillings) being unconnected together, and merely resting upon the outer planking, instead of giving, as they ought to do, support to it. Ships so constructed cannot by any means possess equal strength with those that have the whole of their timbers formed into frames or arches.

(554.) Sir Robert Seppings observes, "that this imperfect mode of practice is peculiar to the English merchant ship-builder; and was pursued even till very lately in his Majesty's Navy, while the preferable system of connecting the ribs was common to other maritime Powers. There cannot be any doubt," he further adds, "that the principle of uniting the frames now adopted in the construction of English ships of war, might with great advantage be also introduced into the mercantile Navy; thereby giving to the ships in that employ additional strength and increased durability, without adding to the expense of building.

Principles employed in Navy might with advantage be adopted in merchant ships.

(555.) There are also great objections to the present

mode of joining together the several pieces of the same rib. In the ordinary way it is done by the introduction of a third piece, technically termed a chock or wedge piece, A, fig. 4. pl. vi.; these pieces amounting to upwards of four hundred and fifty in a 74-gun ship, and not less than that number in an Indiaman of 1200 tons. Of these chocks, not one in a hundred is ever replaced in the general repair of a ship, being not only found defective, but very generally to have communicated their own decay to the timbers to which they are attached. In addition to this, the grain of the rib pieces is much impaired, to give them the curvature required; and that they occasion a great consumption of materials, is obvious, the ends of the two rib pieces being first cut away, and then replaced by the chock.

Great objections to the present mode.

This mode peculiar to the English ship-builder

(556.) This mode of putting together the frame is also peculiar to the English ship-builder, and was introduced about the year 1714; and to the honour of Mr. Nash, the builder of the Royal William, it should be recorded, that he refused to adopt it. When that ship was taken to pieces at Portsmouth, in 1813, Sir Robert Seppings found she was built without the wedge pieces or chocks, to which, in a certain degree, he attributed her strength and durability.

Why chocks were introduced.

(557.) Chocks were no doubt introduced in order to procure the necessary curvature, when crooked or compass timber became scarce, as may be seen in fig. 5. The same curvature, however, may equally be obtained by a different combination of materials, and at a considerable less consumption of useful timber.

Description of frames of a mercantile ship.

(558.) The frames of a mercantile ship, according to the present mode of building, before they are placed and united to each other, may be seen with their chocks or wedge pieces in fig. 6. From imperfect workmanship, also, the surfaces of the chocks are seldom in contact with those of the timbers; and the ends of both are frequently reduced so thin, as to split by the fastenings necessary to secure the planks to the ribs. Thus the ship, in the event of grounding, or even in the act of rolling, derives little support from timbers united only by two narrow edges.

Defects.

(559.) Another great defect, moreover, is, that the ends of the lower ribs or timbers, commonly termed the lower futtocks, fig. 6, are not continued across the keel C, so that no support is given in a transverse direction when the ship touches the ground; nor any aid to counteract the constant pressure of the mast. This great sacrifice of *strength* and *safety* is made for no other purpose than that of giving a passage for the water to the pumps.

(560.) The floor timbers, which by this mode of construction are the only timbers that cross the keel, are also weakened for the same purpose, as shown at D, fig. 6. The conveyance of the water is hence very uncertain, the passage being very frequently choked; the pumps, from its not being practicable to continue them sufficiently low, always leaving from six to eight inches of water in the ship. These compartments, therefore, constantly permit a certain quantity of putrid bilge water, offensive and injurious to the health of all on board.

(561.) The deficiency of strength causes also an alarming insecurity in the plank of the bottom, as shown at E, fig. 6, termed the garboard strake; which, consequently, has no other fastening to the general fabric than its connection with the keel at F, fig. 6, and a slight security at G, fig. 6: hence it is obvious, that in the event of the keel being disturbed, the garboard strake, from its being attached to it, must share the same fate as the keel, and in that case the loss of the vessel would be inevitable.

Improvements of Seppings.

(562.) To obviate these serious defects is the principal object of the excellent Paper given by Sir Robert Seppings in the *Transactions of the Royal Society for* 1820. The principle of this improvement may be seen by referring to fig. 7, the component parts of each rib being of shorter lengths and less curvature, and consequently less grain-cut. They are also rendered more firm and solid by substituting coaks or dowels for chocks or wedge pieces; and the mode of connecting the lower timbers is better adapted, in the event of a ship grounding, to give support and strength to the fabric, as appears by the line denoted by H.

Origin of the idea of dowels or coaks.

(563.) This mode of connecting the ends of the timbers by circular dowels or coaks, as at I, is that which has, from time immemorial, been practised to unite the fellies of carriage wheels; and we learn from Mr. Wood, that the same method has been observed in joining together the separate pieces of the shafts of the stone columns in the ruins of Balbec.

Comparison of the Talavera and Black Prince.

(564.) To contrast the two systems, the Talavera, built according to the new plan, was compared with the Black Prince, constructed with chocks, the result being most favourable to the former. The frame of the Talavera was composed of small timber, hitherto considered applicable only for the frames of frigates. Sir Robert was induced to attempt the construction in this way; from there being a surplus store of small timber in the yard, and from a conviction, that a well-combined number of small timbers might be made equal, if not superior, both in strength and economy, to the large, overgrown, and frequently grain-cut materials, employed in constructing the frames of large ships. The result has shown the correctness of the principle; and its adoption cannot fail to prove of great national advantage, in the application of sloop timber to the building of frigates, and of frigate timber to ships of the line, whenever large timber cannot be procured. On this principle, also, may frigates and small ships of war, or merchant vessels, be built of straight fir, without the assistance of oak or elm, formerly employed to give the necessary curvature of the sides.

Timber commonly applied to small ships may be used for larger ships.

Further description of the principle.

As respects the general safety of the ship, it may be seen, by referring to fig. 8, pl. vi., and fig. 10, pl. v., that the timbers uniformly cross the keel; that the frame of the ship is filled so as to form a compact body to the height marked K; and that only certain internal strakes of plank, or thick stuff, as it is termed, are introduced on the joints of the timbers, for the purpose of imparting strength where every alternate timber necessarily joins, as shown at L. The remainder of the inner planking may be omitted, and dunnage battens, in a perpendicular direction, brought upon the timbers *between* the plank, as shown at M, thereby forming regular spaces between each, as is usual at present *upon* the plank. This will give an increase of stowage in proportion to the thickness of the plank omitted. Water courses, denoted by dotted lines at N, are left in the joints of the timber under the plank, for the purpose of conveying the water to the pumps; which, by this plan, reach below the water, instead of being some inches above, as in former plans. No stagnant water will hence remain, the limber passage, forming a smooth uniform channel, capable of being cleared with ease, should it be required, whenever the hold is unstowed; whereas at present it is inaccessible

in places, and forms compartments for putrid water, without there being any means of removing it.

A ship so constructed may lose planks from its bottom, and also lose its keel.

(565.) It is obvious that a ship constructed on this principle may sustain the loss of certain planks of the bottom, and, also the keel, (which has frequently happened to ships of war on their being taken into dock,) and still reach the place of her destination; when the loss of *either* would be the destruction of a ship built on the present mode. It is evident, also, that a ship constructed on the new plan possesses greater capabilities of stowage, and ampler space for leakage than by the old; by omitting the useless inner planking, and by laying the kentlage on dunnage, leaving a space for the water, which was formerly occupied by the inner lining. This dunnage in the bilge may be formed with the iron kentlage, and thereby serve as ballast, for which it is well calculated from its situation; and by its occupying a space heretofore forming part of the fabric of the ship, cannot but give an increase of stowage.

Mode of closing the openings between the timbers.

(566.) The best mode of closing the openings between the timbers, is by filling the intermediate spaces with pieces of wood, about three inches in depth, and of such lengths as the inferior conversions will afford. These fillings are to be well calked, after which the exterior plank is to be brought on. When the works are going on within board, similar pieces are to be fitted internally, and afterwards taken out for the purpose of filling the spaces between the pieces so fitted with a mixture of Parker's Roman cement and drift sand, in the proportion of two to one, the opening being previously well payed with coal tar. Where there is sufficient space, a brick may be introduced, provided there is room for cement between it and the timbers. When filled in to within about two inches of the surface of the frame, the three-inch pieces, already fitted and taken out, are to be well driven in and calked, thereby leaving no space unoccupied. These pieces may even be driven below the surface of the timber, leaving water courses to convey the leakage to the pumps in channels. Before the launching or undocking of ships built on this principle, it has been the practice to inject the part filled in with mineral tar, by means of a simple forcing pump, boring holes in the joints of the timbers for the introduction of the pipe. By following this method, the air will be excluded, which, as experience has shown, tends much to the durability of the fabric. If what is here recommended be attended to, and mercantile ships be built under roofs, as ships of war now are, durability will be obtained in addition to safety, from the mode of their construction.

How wooden knees are rendered unnecessary.

(567.) The beams are to be attached to the sides, as shown at O, fig. 8. rendering wood knees unnecessary, and requiring only a small number composed of iron. In fig. 11, pl. v. the portion P illustrates the old principle of framing the stern with transoms, and Q the new one, having timbers similar to the bow, omitting the transoms below the wing or upper transom. By introducing the new principle on which the floors are made, the necessity of using the valuable compass timber, hitherto required, and which is with so much difficulty procured, is altogether avoided. Uniform support is thus given, and also increased room for stowage. In mercantile ships above 500 tons, Sir Robert Seppings recommends plate iron to be laid diagonally, as shown in fig. 10, pl. v.

Plate iron to be laid diagonally.

Proof of strength of the Malabar.

(568.) The important principle now recommended, not only causes a decrease in the consumption of materials, and obviates the difficulty of procuring the necessary curvature, but also affords protection from worms externally, and vermin internally. Leaks may be more easily discovered and stopped than by the old method; and as a beautiful experimental proof of increased strength the Malabar, of 74 guns, built at Bombay, arrived at Portsmouth, loaded to her upper deck with timber, having during her passage encountered four heavy gales of wind, without showing a symptom of weakness. This ship had no other attachment for her beams than the internal hoops and thick water way; the iron knees having been omitted, from the difficulty of procuring them in India, until her arrival in this Country; thus supporting her cargo without the aid of knees, either of wood or iron.

Mr. Edye's valuable Tables.

(569.) The publication of Mr. Edye's valuable Work on *Naval Calculations*, has brought the great numerical results of ship-building into a very convenient point of view. The praiseworthy industry that has led to the formation of the numerous Tables contained in it, will, we hope, meet with its due reward. To the theoretical cultivator of Naval Architecture, as well as to the practical shipwright, this collection of constants cannot but prove of the greatest value.

Dimensions of different ships.

The following Table contains the dimensions* of different ships, with their light and load draughts of water and height of ports.

* We regret that our limits will not permit us to do more than allude with the greatest brevity to the important history of the dimensions of ships. It has been by very slow and gradual steps that our Navy has advanced in this important particular. In 1677 the length on the gun deck of a 100-gun ship, amounted but to 165 feet, and in the establishment of 1745 it had increased only to 178 feet. Spain was the first nation that increased the dimensions of ships to any considerable extent, and France followed her example with better success. The capture of the Princess of 70 guns from the Spaniards in 1739, pointed out the necessity of our increasing the dimensions of our largest class of two decks; but the French and Spanish Navies were long inferior to the English in the want of three-deckers, of which experience taught them the largest classes were much too powerful for their largest two-deckers. It was not till after the Peace of 1763, that either France or Spain possessed a single ship of three decks. It was the English three-decker, the Royal George of 100 guns, and of 2046 tons burthen, launched in 1756, that gave so great an impulse to ships of this class. The Commerce de Marseilles, however, exceeded our present first-rates in length by 3 feet 4 four inches, in breadth by 1 foot 3 inches and a half, and in tonnage by 145 tons.

By adopting 100 for the breadth of a three-deck ship of each of the following Nations, the proportional lengths are those recorded in the following Table:

	Proportional Breadth.	Numbers for the Length.
Spanish	100	358
Swedish	100	372
French	100	380
English	100	383

And in the largest class of ships of two decks of 80-guns and upwards, these proportional numbers are as follows:

Spanish.............	100 Breadth.	362 Length
Danish	100	367
Swedish.............	100	369
French	100	375
English.............	100	376

By taking the smaller ships of two decks, the proportional numbers become:

English	100 Breadth.	361 Length.
Spanish	100	365
Swedish.............	100	365
French	100	365
Danish	100	373

And for frigates, we have the following:

Spanish.............	100 Breadth.	367 Length.
French (Impérieuse) ..	100	375
English (Leda)	100	376
Danish	100	377
Swedish	100	379
French (Niobe)	100	383
English (Portland) ...	100	398

Number of Guns	120	80	74	Razée. 50	52	46	Razee Corvette. 26	28	Corvette. 18	Brig. 18	Brig. 10	Schooner	Cutter.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
Length of Deck	205 0	196 1½	176 0	173 8	172 0	150 1½	145 0	113 8	112 0	100 0	90 0	80 0	67 3
of Keel for Tonnage	170 11	161 11½	145 1	144 8	144 9	125 1⅛	121 9⅜	94 8¾	92 1⅜	77 3½	73 7⅛	64 5½	51 4
Breadth for ditto	53 6	51 5½	47 6	47 10	43 8	39 11	38 2	31 6	30 6	30 6	21 6	23 0	21 3
Extreme breadth	54 5	52 0¼	48 2	48 6	44 2	40 3	38 6	31 10	30 10	30 9	24 8	23 2	24 5
Depth in Hold	23 2	22 6	21 0	13 10¾	14 6	12 9	13 3	9 0	13 10	12 9	11 0	9 10	10 7
Burthen in Tons...... No.	2602	2279	1741	1761	1468	1063	944	500	456	382	235	183	161
	Ft. In.	Ft. In.	Ft. In.	Ft. In. (12 inches additional keel.)	Ft. In.	Ft. In.	Ft. In. (6 inches additional keel.)	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
Draught of water. Light. Forward	15 10	13 9	13 5	13 1	12 2	10 9	10 11	9 8	10 0	6 6	7 9	6 1	5 4
Draught of water. Light. Aft	18 2	18 4	17 6	17 2	15 0	15 6	11 4	11 10	11 10	11 4	10 2	9 0	11 10
Draught of water. Load. Forward	24 7	21 9	20 11	20 3	19 5	17 6	17 0½	15 2	14 8	11 4	11 5	9 2	7 7
Draught of water. Load. Aft	26 0	25 0	23 9	21 6	20 5	19 2	18 5½	15 7	15 3	14 7	12 6	11 8	14 5
Height of Ports. Fore	6 10	8 10	7 6	9 3	9 0	8 1	9 4	5 2	5 7	5 5	4 9	4 7	5 9
Height of Ports. Midship	5 6	6 1	5 8	8 3	7 10	7 3	8 5	4 11	4 11	4 9	4 4	3 5	3 2
Height of Ports. After	6 6	6 11	5 9	8 4	8 10	8 1	9 10	5 5	5 10	5 10	4 8	3 7	3 11

Analysis of the rates of labour.

(570.) An exact analysis of the rates of labour of the different artisans employed in building a ship of war, cannot but be of the greatest value.

In the following Table we have the rates per ton, and also the total amounts.

The Rate per Ton for Labour on all Classes of Ships and Vessels with the Total Amount.

Number of Guns	120	80	74	52	46	28	Corvette. 18	Brig. 18	Brig. 10	Schooner.	Cutter
Rate per Ton for	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Shipwrights	4 13 5½	4 2 8	4 7 4	4 0 0	4 11 1	5 15 2	4 12 0	4 14 9	4 16 0	4 11 10	4 6 3½
Calkers	0 4 11	0 4 0	0 4 1	0 3 5	0 3 8	0 5 0½	0 5 4	0 5 4½	0 6 5	0 6 5	0 5 7
Joiners	0 12 7	0 10 6	0 11 0	0 6 2	0 7 6	0 11 9	0 12 7	0 11 5¼	0 12 3	0 11 7	0 12 0
Smiths	0 7 6½	0 6 4	0 6 6	0 6 7	0 7 8	0 6 4½	0 5 3	0 4 0¾	0 2 9	0 2 10	0 2 8½
Painters	0 1 8	0 1 6	0 1 6	0 1 3	0 1 6	0 2 0	0 1 4	0 1 2½	0 1 4	0 1 6	0 1 5
Total per Ton	6 0 2	5 5 0	5 10 5	4 17 5	5 11 5	7 0 4	5 16 6	5 16 10	5 18 9	5 14 2	5 8 0
Total amount for	£. s.	£. s.	£. s.	£. s.	£. s.	£. s.	£. s.	£. s.	£. s.	£. s.	£. s.
Shipwrights	12172 6	9435 0	7608 17	5872 0	4842 7	2878 18	2090 18	1812 5	1130 15	840 0	694 15
Calkers	644 10	445 16	355 13	251 0	201 6	126 19	123 13	102 10	73 9	58 10	45 2
Joiners	1639 14	1196 5	952 17	450 0	398 6	296 6	290 15	219 3	114 18	106 2	96 3
Smiths	966 13	721 0	567 3	480 0	404 5	156 8	120 0	78 2	30 4	26 2	22 0
Painters	220 0	178 0	130 10	90 0	80 0	50 0	31 0	22 0	16 0	14 6	12 0
Total amount*	15643 3	11976 1	9615 0	7143 0	5926 4	3508 11	2656 6	2234 0	1395 6	1045 0	870 0

Great difference in rates of labour for different ships.

(571.) It appears from this Table that the rates of labour for the different classes of ships are by no means constant. In the shipwrights, for example, there is a difference between the maximum rate for the 28-gun ship, and the minimum rate for the 52-gun frigate, amounting to no less than £1. 15*s*. 2*d*, per ton. It would be curious to trace the cause of so great a difference. The cheapest ship for the calkers and joiners is also the 52-gun frigate; but the maximum price for the former trade is found in the 10-gun brig and the schooner; and for the latter trade, the greatest price is found in the 120-gun ship, and the 18-gun corvette. The greatest rate of labour for the smiths is found in the 46-gun frigate, and the least in the cutter. The cheapest vessel for the painters is the 18-gun brig, and the dearest the three-decker. Taking all the ships, the dearest vessel per ton is the 28-gun ship, and the cheapest the 52-gun frigate. We might pursue these comparisons further, did our limits permit.

* From these sums 20 per cent. must be deducted to bring them to the Peace rates.

Other relations of rates of labour and materials.

(572.) The relations, also, of the rate per ton for labour and materials are deserving, also, of an attentive consideration. In the fourth and fifth columns of the succeeding Table, this relation is exhibited, the timber exceeding the labour in the greatest ratio in the 120-gun ship, and the least in the 18-gun brig.

Naval Architecture.

Number of Guns.	Rate per Ton for Labour. £.	s.	d.	Rate per Ton for Materials. £.	s.	d.	Ratio of Labour to Cost of Materials.	Total Expense of Labour. £.	Total Expense of Materials. £.	Total Cost of Ship's Hull. £.	Total Cost of Masts and Yards. £.	Total Cost of Rigging and Blocks. £.	Total Cost of Furniture and Sea Stores. £.	Total Expense of Equipment.* £.	Cost per Gun to the nearest Unit. £.
120	6	0	2	29	18	7	5 : 31	15643	77878	93521	3879	2994	16805	117199	977
80	5	5	0	23	7	9	5 : 25	11976	53303	65279	3506	2997	15114	86896	1086
74	5	10	5	28	0	3	5 : 30	9615	48773	58388	2994	2691	12433	76506	1034
52	4	17	5	20	3	2	5 : 26	7143	29601	36744	2598	2013	9512	50867	978
46	5	11	5	20	18	5	5 : 24	5926	22237	28163	1477	1676	7952	39268	854
28	7	0	4	24	4	1	5 : 22	3508	12103	15611	745	764	4434	21554	770
Corvette 18	5	16	6	19	12	7	5 : 22	2656	8954	11610	635	792	3706	16743	930
Brig .. 18	5	16	10	17	13	9	5 : 20	2234	6758	8992	526	610	3265	13413	745
Brig .. 10	5	18	9	19	11	9	5 : 21	1395	4604	5999	327	395	2075	8796	880
Schooner ..	5	14	2	19	9	0	5 : 22	1045	3560	4605	200	170	1380	6355	
Cutter	5	8	0	19	6	5	5 : 23	870	3110	3980	351	171	1368	5870	

Loads of timber for different ships.

(573.) The next Table contains a statement of the loads of rough timber, plank, &c. required for building each class of ship and vessel; of the quantity that one man can work up in a twelvemonth in building; and of the number of men it will take to complete a ship in that time for launching, calculated at the War rate.

Number of men to build a ship of each class.

Rate of Ship	120	80	74	52	46	28	Corvette. 18	Brig. 18	Brig. 10	Schooner.	Cutter.
Quantity of Loads required	5880	4339	3600	2372	1800	963	624	471	337	250	186
Ditto, that one Man can work in a Twelvemonth	29½	28¾	29¾	25¾	23¾	22	18½	17½	18½	18½	17
Number of Men to build a Ship in the same period	200	153	122	91½	76	44½	33¾	27¾	18	13½	11
If estimated at the Peace rate, the following will be the results.											
Quantity of Loads for one Man in a Twelvemonth.............	35½	34¼	35¾	30	28½	26	22¼	21	22	22	20½
Number of Men to build a Ship in the same period	160	122½	97	69	60¾	35½	27	22¼	14½	10¾	8¾

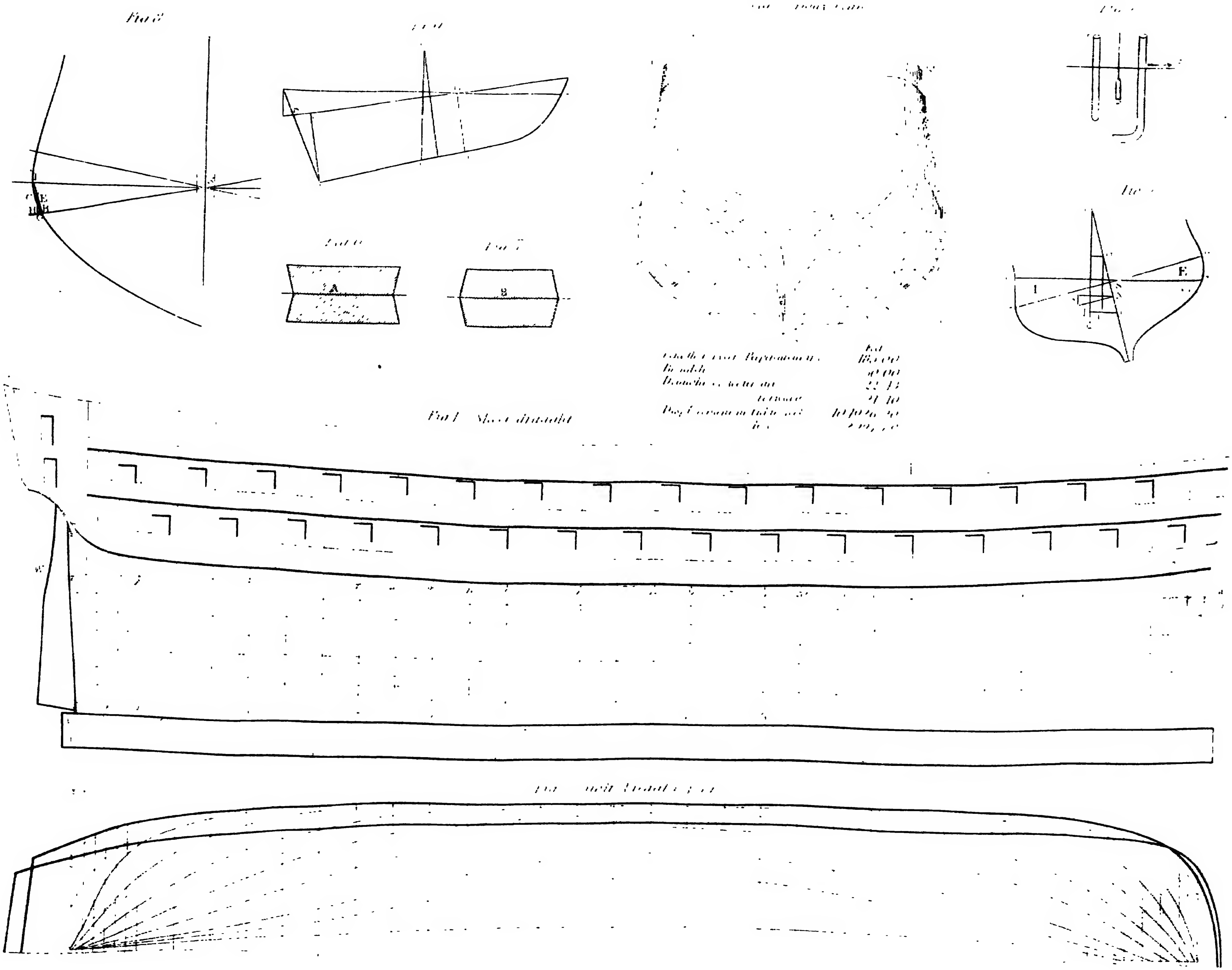
Number of men to rig a ship of each class.

(574.) The time in which 20 riggers can fit the rigging and blocks of each class of ship and vessel is given in the following Table:

Class of Ship and Vessel.	Hours.
120 Guns	300
74 to 60	285
50	260
46	230
28	140
18 Corvette	110
18 Brig	105
10	80

(575.) With this Table we reluctantly quit the important subject of Naval Architecture. It is one of growing interest to the World, and the present distinguished Surveyor of the Navy, Captain Symonds, in the ships already built and now building by him, has so largely increased the dimensions of ships, that we cannot but anticipate the most splendid results from his important plans.

* 20 per cent. must be deducted from these sums for labour, and 18 per cent. for materials, to reduce them to the Peace rates. The Cornwallis of 74 guns, of 1809 tons, was built at Bombay of teak, at £30. 14*s.* a ton. The Trincomalee frigate, of 1065 tons, at the same place, of the same material, at £29. 8*s.* 2*d.* per ton. The Victory, also, of 382 tons, at £23. 9*s.* 7*d.* a ton; the Zebra, of 385 tons, at £21. 6*s.* 7*d.* a ton; the Sphinx, of 239 tons, at £24. 6*s.* 6*d.* a ton; and the Camden, of 240 tons, at £25. 3*s.* 10*d.* a ton.



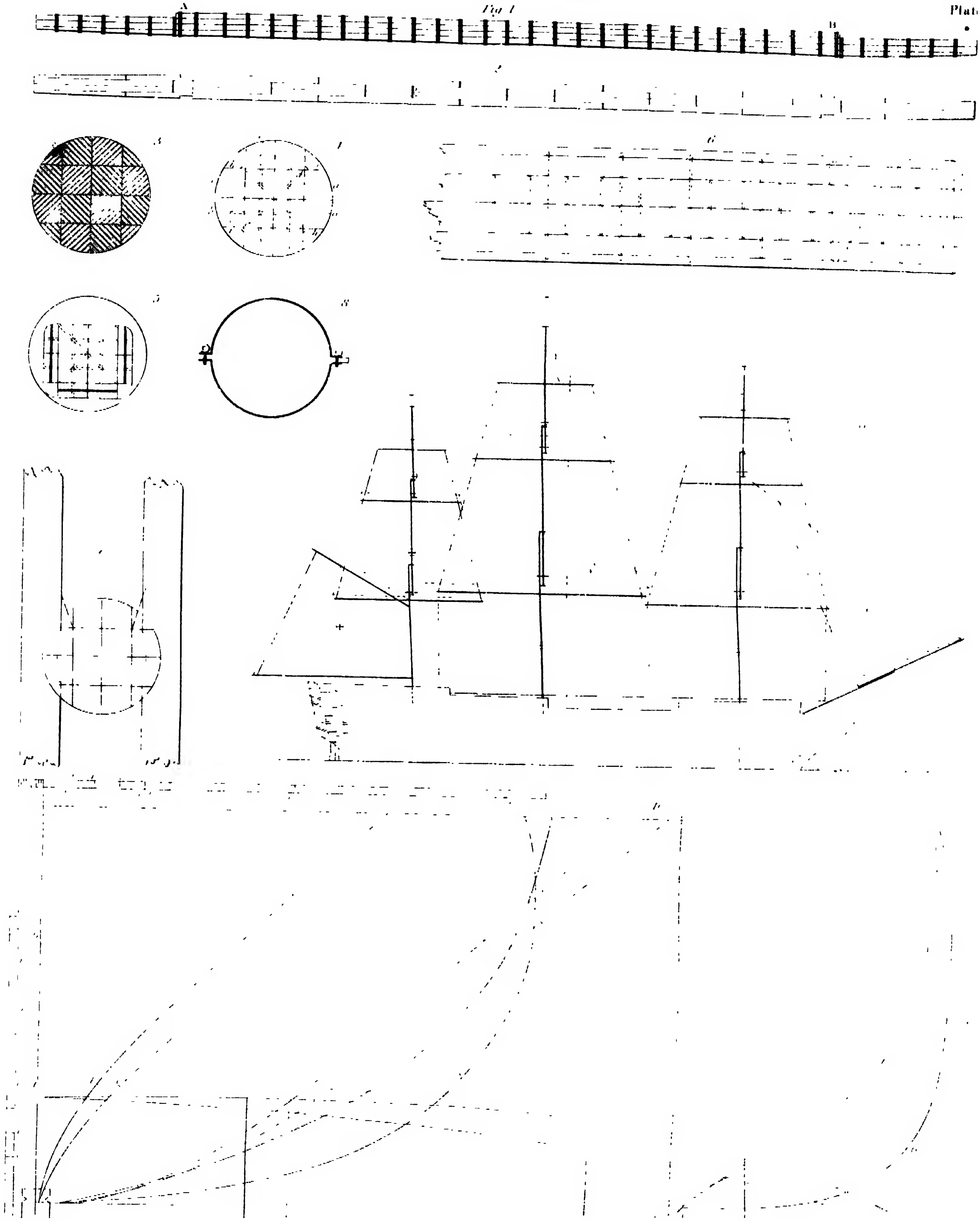
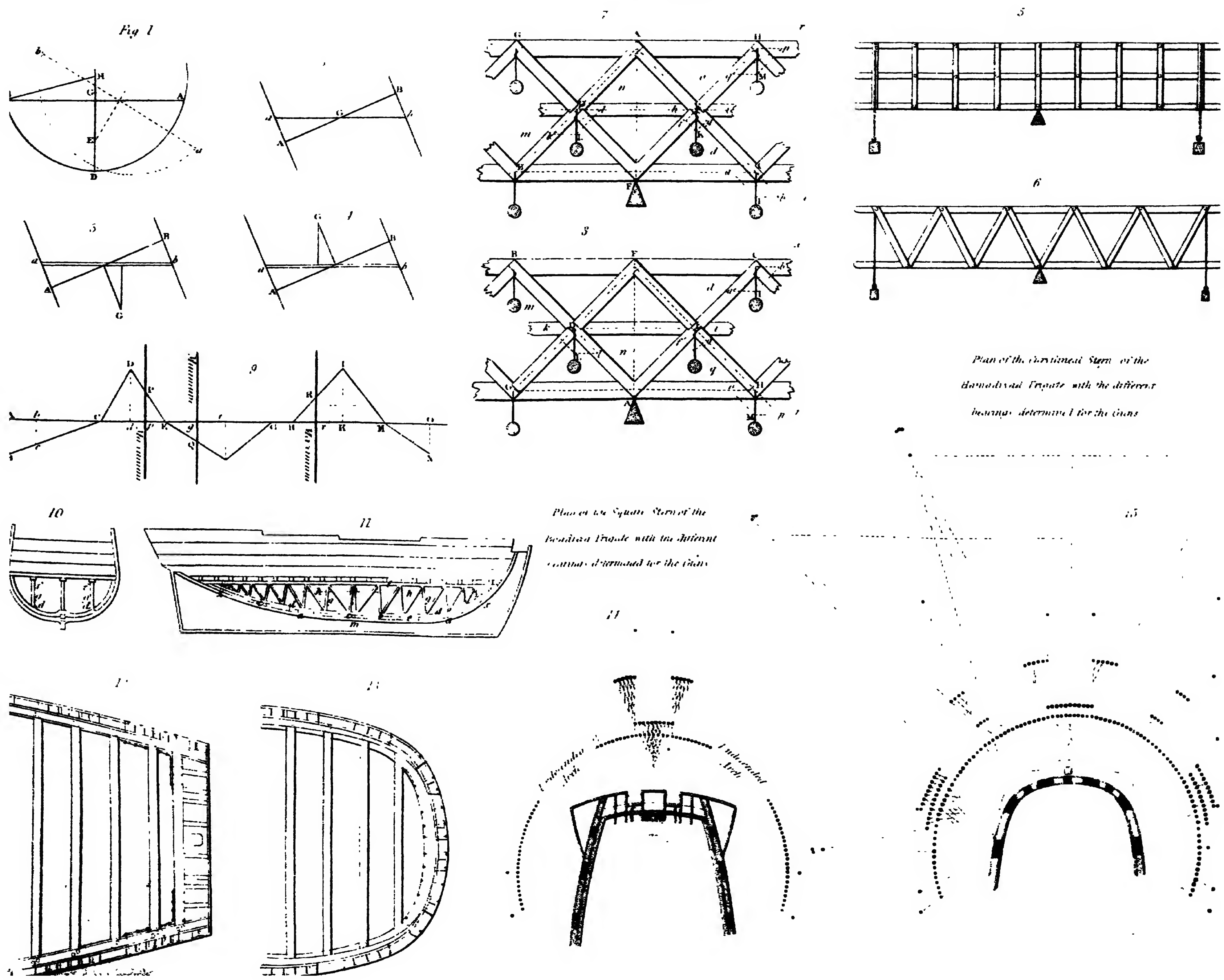


Fig. 1
A
B

NAVAL ARCHITECTURE.



Plan of the Stern.

Fig. 4.

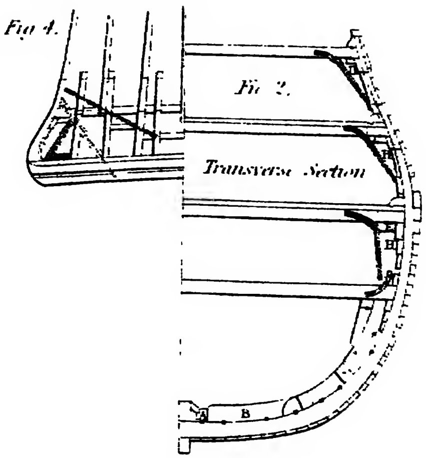


Fig. 2.

Transverse Section

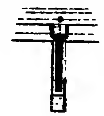
A.A Lumber strake & additional Keelson forming abutments for the lower part of diagonal frame.

B.B. Timbers of the diagonal frame

C Longitudinal pieces to ditto

D. Trusses to ——— ditto

Fig 3
Plan of Iron Knee.



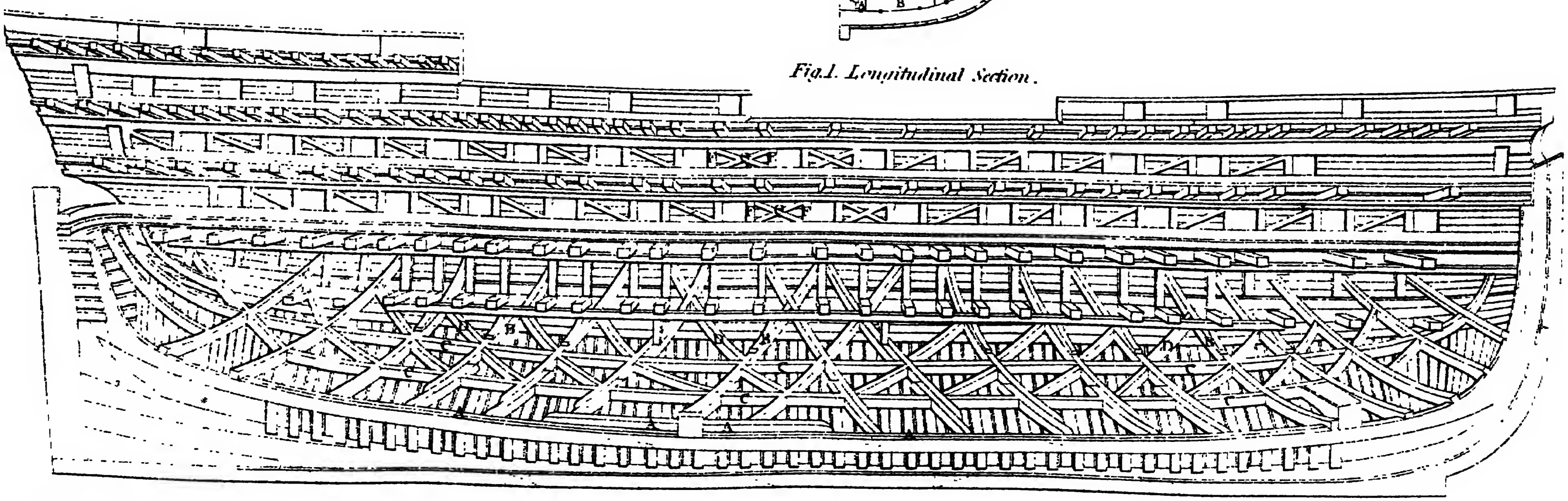
E Internal hoop or middeck shelf piece forming abutment for the upper part of the diagonal frame.

F Abutment pieces for trusses between ports.

G Trusses

H.H. Chocks under shelf piece for Iron Knees.

Fig. 1. Longitudinal Section.



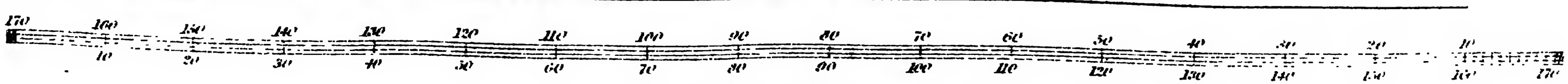
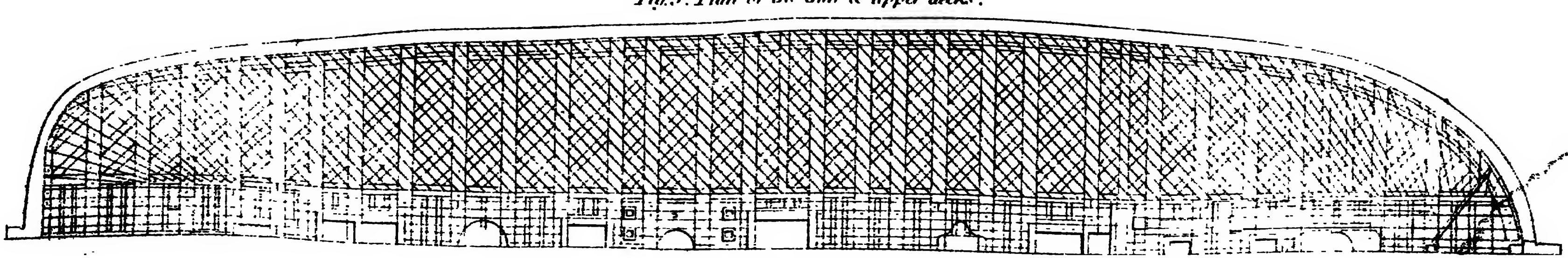
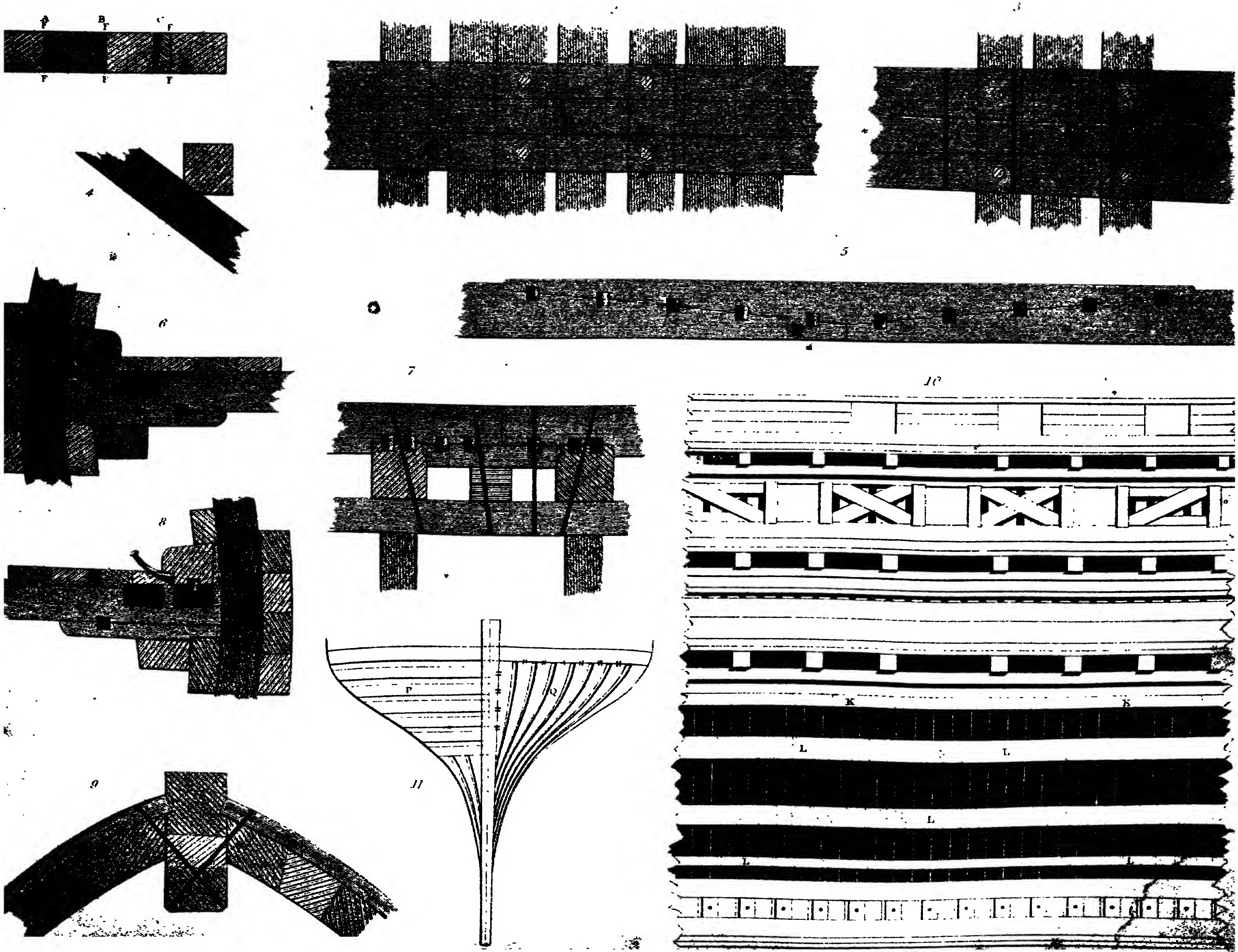


Fig. 5. Plan of the Gun & upper decks.




A
B
C
F
2
3
4
5
6
7
8
9
10
11
P
Q
K
L

NAVAL ARCHITECTURE.

	Feet	In.
Length on the Gun Deck	205	5
of the Keel for Tonnage	170	21
Breadth Extreme	54	8
Moulded	53	11
Depth in Hold	23	2
Burthen in Tons	Nº 2705	

Number and nature of Guns	Num.	Pr.	N.	Pr.
Gun Deck	30	32	2	68
Middle D.ᵏ	34	32		
Upper	34	32	Carronades	
			Nº	Pr.
Quarter	2	18	14	32
Fore Castle	2	18	2	32

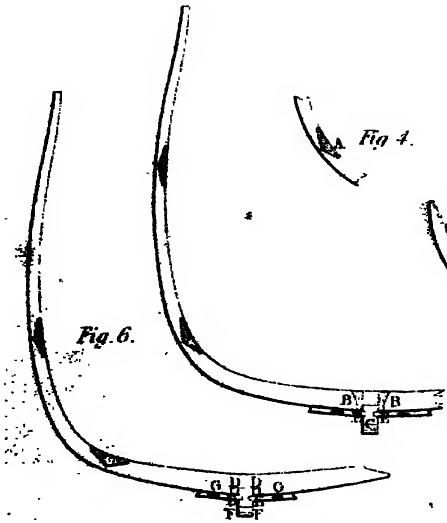


Fig. 6.
Fig. 4.


Fig. 5.

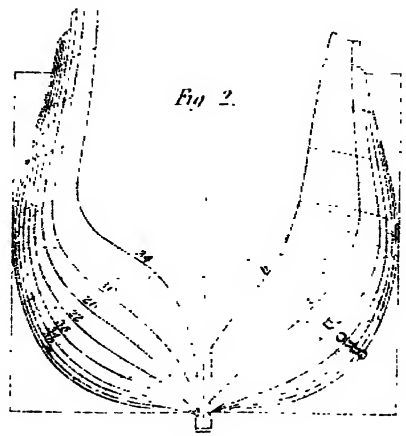


Fig. 2.

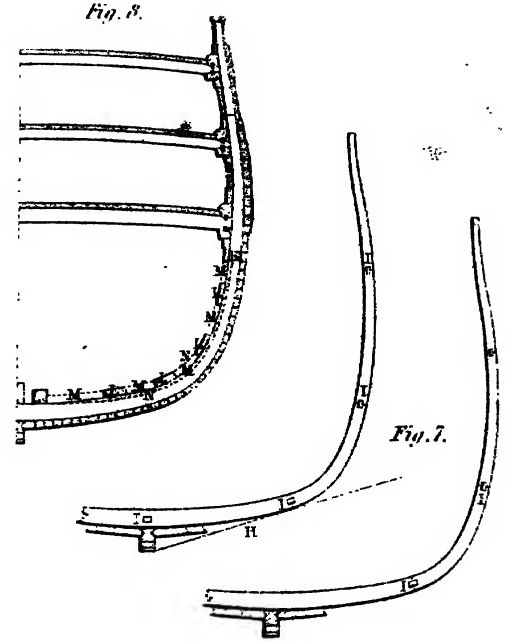


Fig. 8.
Fig. 7.

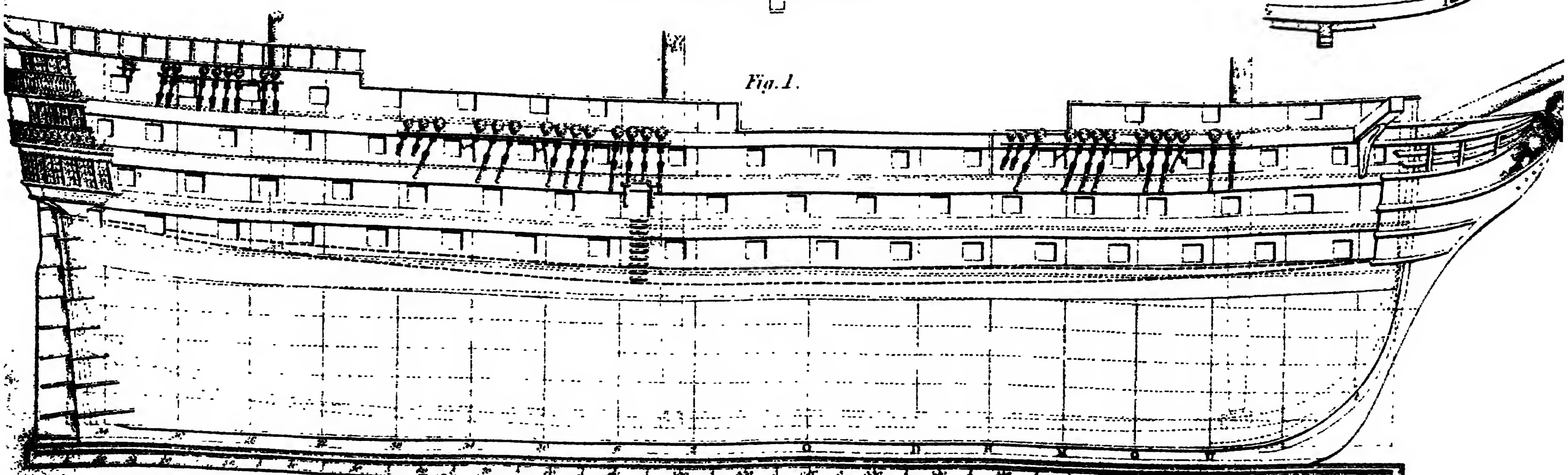


Fig. 1.

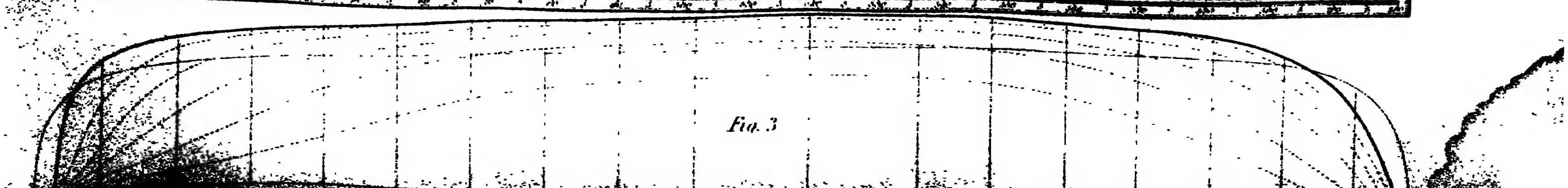


Fig. 3.

THE following Treatise has, for the accommodation of different classes of readers, been divided into two Parts.

In the First an explanation is given of the relations of Crystals, founded upon the characters and positions of their planes; and in the Second, those relations are investigated and demonstrated mathematically.

The following characters are used in this Treatise.

A, E, I, O, on the angles of primary terminal planes. (98.)

B, C, D, F, on the primary terminal edges. (98.)

G, H, on the primary lateral edges. (98.)

P, M, T, on the primary planes shown in the figures. (98.)

$\|$ P, $\|$ M, $\|$ T, primary planes parallel to P, M, T. (106.)

v, general expression of the law of decrement. (124.)

$\overset{v}{A}$, $\overset{v}{E}$, &c., simple decrement on the terminal angles. (124.)

A_{v}, E_{v}, &c., *general* symbol of simple decrements on the lateral angles. (124.)

$\overset{r}{B}$, $\overset{r}{H}$, &c., decrements on terminal or lateral edges. (125.)

(B_r, B'_y, B''_r) intermediary decrement. (127.)

0, no decrement, absence of any symmetrical plane, (127.) as $\overset{r}{\underset{0}{B}}$, when only the upper plane of mod. *e* of the cube occurs in the Crystal, (127.) or $\overset{0}{A}$ $\overset{v}{A}$, when a plane occurs only on the alternate angles. (128.)

(0) absence of a symmetrical intermediary plane. (127.)

a, *b*, *c*, &c., on the modifying planes.

$\bar{a}$, $\bar{b}$, $\bar{c}$, $\bar{d}$, modifying planes on the angles of the doubly oblique prism, and $\bar{e}$, of the oblique rhombic prism, when they cut the *terminal* plane parallel to a diagonal. (106.)

$,a$, plane *a* of doubly oblique prism when it cuts M parallel to a diagonal. (106.)

$a_,$, the same modification when it cuts T parallel to a diagonal, (106.) and so of $,b$, $b_,$, $,c$, $c_,$, &c.

$b_{,,}$, &c., when an angle is modified by *two* symmetrical planes, as in the square prism, which cut the lateral planes parallel to a diagonal. (103.)

$\frac{b}{2}$, when only one of such planes appears on the left in the Crystal. (103.)

$\frac{b}{2}$, when the single plane is on the right. (103.)

$\frac{b}{2}$ *r*, when only one of two *intermediary* planes occurs on the right. (103.)

$l\frac{b}{2}$, when the single plane occurs on the left. (103.)

$\frac{a}{2}$, $\frac{b}{2}$, &c., when planes occur only on the *alternate* angles or edges of the cube. (100.)

$\frac{a}{2}\|$, $\frac{b}{2}\|$, &c., when the angles or edges of the cube are modified by only one half the number of planes required by the law of symmetry. (101.)

m, *n*, *o*, comparative lengths of primary edges. (133.)

p, *q*, *r*, comparative lengths of edges of the defect. (121.)

P,*a*, P,*b*, *a*,*b*, &c., inclination of P on *a*, or *b*, of *a* on *b*, &c. (81.)

PART I.

Definitions and Explanations.

(1.) The object of the Science of Crystallography, regarded as a branch of Mineralogy, is to describe and explain the relations which subsist among the various crystalline forms of minerals, so as to enable the Mineralogist to determine the species of a mineral from the characters of its Crystals.

These relations will be explained by first separating the Crystals into groups, and then selecting one from each group as a standard, with which the remainder of the group may be compared.

(2.) The standard so selected will be termed the *primary form*, and the remainder of the group *secondary forms*, as will be afterwards more fully explained.

(3.) A *Crystal*, in Mineralogy, is any mineral solid, whether transparent or opaque, contained within *natural* surfaces, generally plane, but occasionally curved, and symmetrically arranged.

(4.) These surfaces, as *a*, *b*, *c*, fig. 1, are called *planes* or *faces*, and to distinguish them from such as are developed by splitting a Crystal, they are called its *natural planes*.

The plane *a*, and that on which the figure is supposed to rest, are by some authors called *summits*, or *bases*, but they are more conveniently distinguished as *terminal planes*; the planes *b* and *c*, and those parallel to them, are *lateral planes*.

(5.) Crystals may sometimes be split in directions parallel to their natural planes, and frequently in other directions.

The splitting a Crystal in any direction, so as to produce a new plane, is termed *cleaving* it, and the Crystal is said to have a *cleavage* in the direction in which it may be so split.

(6.) The planes produced by cleaving a Crystal are called its *cleavage planes*. But when a cleavage merely separates adjacent Crystals, without dividing the Crystals themselves, the planes then developed are termed *planes of composition*.

Both the natural and cleavage planes of Crystals are sometimes found to differ in lustre and other characters according to their position on the Crystal.

(7.) An *edge*, as *d*, fig. 1, is the line produced by the meeting of two planes.

If the two planes which produce an edge, are those of a primary form, the *edge* is termed *primary*. If they are secondary, and belonging to the *same modification*, the *edge* is termed *secondary*. But if an edge be produced by the meeting of a primary and a secondary plane, or

of different secondary planes, it is termed *an edge of combination.*

The edges of the terminal planes, as *d*, *e*, *m*, *n*, fig. 1, are *terminal edges*, and *f*, *g*, *h*, produced by the meeting of the lateral planes, are *lateral edges*.

(8.) A *plane angle*, or, as it is more commonly termed, *an angle*, is formed by the meeting of any two lines or edges, which are sometimes said to *contain* the angle. The angles *d o e*, *d o g*, fig. 1, are formed by the meeting of the lines *d o*, *o e*, and *d o*, *o g*.

(9.) A *solid angle* is produced by the meeting of three or more planes, as at *o*, fig. 1.

(10.) The *measure*, or, as it is sometimes termed, the *value of an angle*, is the number of degrees, minutes, &c. of which it consists; these being determined by the portion of a circle which would be intercepted by the two lines forming the angle, supposing the point of their meeting to be in the centre of the circle.

For the purpose of measuring angles the circle is divided into 360 equal parts, called *degrees*; each degree into 60 *minutes*; each minute into 60 *seconds*; each second is sometimes further subdivided into 60 *thirds*; and so on if more minute divisions be required. And these divisions are thus respectively designated, 360°, $60'$, $60''$, $60'''$.

If one fourth of the circle be intercepted by the two lines *a o*, *o b*, fig. 2, which meet at an angle *a o b* in the centre, those lines are perpendicular to each other, the angle they contain is 90°, and is termed a *right angle*.

If less than one fourth of the circle be so intercepted, as by the lines *o b*, *o c*, the angle *b o c* is less than 90°, and is said to be *acute*. If it measure more than 90°, as it would if the angle were formed by the lines *a o*, *o c*, it is called *obtuse*.

(11.) The *planes* of a Crystal are said to be *similar* when their corresponding edges are proportional and their corresponding angles equal.

(12.) *Edges* are *similar* when they are produced by the meeting of planes respectively similar at equal angles.

(13.) *Angles* are *similar* when they are equal, and contained within similar edges respectively.

(14.) *Solid angles* are *similar* when they are composed of equal numbers of plane angles, of which the corresponding ones are similar.

(15.) The homogeneous particles, by the regular aggregation of which Crystals are conceived to be produced, are termed *molecules*; and these are assumed to be separable, but not divisible, by splitting or otherwise breaking the Crystal.

These *molecules*, which relate properly to the Crystal, must, when the crystallized mineral is not a simple body, be carefully distinguished from the *elementary particles* of which the mineral itself is composed. Sulphur and lead are the elementary particles of galena, in which they are chemically united; but it is the *molecules* of galena which are conceived to form the crystalline mass.

(16.) The same species of mineral is frequently found crystallized in a considerable variety of forms.

(17.) The term *form* as it is used here, and as it will be employed throughout this Treatise, does not refer to the actual figure of any particular Crystal, but to that perfect figure which the Crystal would present if all its parts were truly proportional and symmetrical.

Thus one of the *forms* of the Crystals of fluate of lime is a cube, all of whose planes are equal squares; but the *actual figures* of the Crystals which represent that form, are probably never contained under equal square planes, but under unequal rectangular ones, which differ also in different Crystals.

(18.) From among the various forms belonging to any species of mineral, some particular one may be selected from which the others might be derived in a manner which will be afterwards explained. This form does not, however, always occur among the *natural* Crystals of a species, but is sometimes inferred from cleavage or other circumstances.

This parent Crystal has been already termed a *primary form*, and the others which are conceived to be derived from it, *secondary forms*.

(19.) The selection of a figure which is to be regarded as the primary form of a species, is in some degree arbitrary, as will be afterwards shown. And the number of different primary forms is also within certain limits a matter of choice.

The following have been adopted in this Treatise, because they appear to afford the most simple explanations of the relations of Crystals, and thus tend to facilitate the study of this important and interesting branch of Mineralogy.

(20.) The *cube*, fig. 3, contained within six square planes. The *regular tetrahedron*, the *regular octahedron*, the *rhombic dodecahedron*, and the *pentagonal dodecahedron*, and their modifications, are secondary forms of the cube, and will consequently be referred to that figure as their primary form.

(21.) A *right prism* with a *square base*, or *square prism*, fig. 4, in which the edge B is always greater or less than G. The *octahedron with a square base*, and its modifications, will be referred to this prism as its primary form.

(22.) A *right rhombic prism*, fig. 5, whose lateral planes M, M′ are equal. These planes may be either square or rectangular. The *octahedron with a rhombic base*, and the *right rectangular prism*, with their modifications, are secondary forms of this prism.

(23.) An *oblique rhombic prism*, fig. 6, whose lateral planes M M′ are equal, oblique-angled parallelograms. The *right oblique-angled prism* and its modifications will be referred to this form.

(24.) A *doubly oblique prism*, fig. 7, whose terminal and lateral planes are oblique-angled parallelograms. The only equality subsisting among these planes, is between each pair of parallel ones.

(25.) The *rhomboid*, fig. 8, a solid contained within six equal rhombic planes, and having two of its solid angles, *a*, *b*, composed of three equal and similar plane angles; these are sometimes called *summits*.

The *regular hexagonal prism* being a secondary form of the rhomboid, will be referred to that figure as its primary form.

(26.) The *secondary* forms of Crystals consist of all those varieties which differ from the primary, and which, although extremely numerous, may be arranged in a few general groups, as will appear in the sequel.

(27.) The *general group*, or *series* of Crystals, related to either of the preceding primary forms, constitutes what is sometimes termed a *system of Crystallization*.

(28.) And a *particular group*, or *individual series* of Crystals, belonging to a *particular mineral*, to whatever *system* it may appertain, is sometimes termed a *series of Crystallization*.

(29.) A line, as *i k*, or *p q*, fig. 1, drawn through

two opposite angles of any parallelogram, and dividing it into two equal parts, is called a *diagonal* of that plane.

In the oblique rhombic prism, fig. 6, the doubly oblique prism, fig. 7, and the rhomboid, fig. 8. The line *a c*, which appears to lean from the spectator, is termed the *oblique diagonal*, and the line *f g* of the oblique rhombic prism, and *d f* of the rhomboid, the *horizontal diagonal*.

The line *d f* of the doubly oblique prism may also, for the sake of uniformity, be termed its horizontal diagonal; although from the nature of the figure, that line must be in some degree oblique when the lateral edges are perpendicular.

(30.) The *diagonal plane* of a solid, as *i k p q*, fig. 1, is an imaginary plane passing through the diagonal lines of two parallel planes, dividing the solid into two equal parts.

A diagonal plane passing through the oblique diagonal of the oblique rhombic prism or rhomboid is termed the *principal section* of each solid.

(31.) The *axis* of a Crystal is an imaginary line passing through the centre of the solid.

That which also passes through the centres of the terminal planes of a cube or prism is termed a *prismatic axis*.

From the regularity of figure of the cube it may be said to have a prismatic axis in three directions.

That which passes through two opposite solid angles of a cube or prism is termed an *oblique axis*.

That which passes through the centres of two lateral planes of a prism may be termed a *horizontal axis*.

The axis of a pyramid passes through its terminal point and through the centre of its base.

The axis of a rhomboid is a line passing through its two summits.

The diagonals and axes of Crystals and the diagonal planes are frequently referred to in describing the forms of Crystals.

(32.) A Crystal is said to be *in position*, when it is so placed, or held, as to permit its being the most easily and precisely observed and described.

The cube rests on one of its planes, and all prisms on their respective bases.

The rhomboid is supposed to be held with its axis vertical.

(33.) The different primary forms stand in the following relations to each other.

If we imagine the lateral edges of the cube, fig. 3, to be lengthened or shortened, a square prism would be produced.

It will facilitate our description of the relation of some of the primary forms to certain others, if we conceive the edges to be formed of wires, united at the solid angles by universal hinges or joints, and thus rendered movable in every direction; and, together with the axis, capable of being lengthened or shortened.

If we conceive one of the oblique axes of the cube to be lengthened, the resulting figure would be an *acute* rhomboid. If the axis were shortened by bringing two opposite solid angles nearer together, an *obtuse* rhomboid would be produced.

If two opposite lateral edges of a square prism be supposed to approach each other, so as to shorten one of the diagonals of the terminal plane and lengthen the other, the resulting figure would be a right rhombic prism; and if this prism were forced from its perpendicular in the direction of either of the diagonals of its terminal plane, an oblique rhombic prism would be produced.

And if this were again made oblique in the direction of a terminal edge, a *doubly oblique prism* would be the result.

(34.) The first formation of a Crystal is supposed theoretically to take place by the aggregation of a few homogeneous molecules around a single central one, so as to produce a small solid precisely similar in form to the molecules composing it.

(35.) Crystals so formed are conceived to increase in magnitude by the continual additions of laminæ, or plates of similar molecules to their surfaces.

These plates are theoretically supposed to be either single, that is, of the thickness of single molecules, or to be double, triple, &c., that is, of the thickness of two, three, or more molecules.

Fig 9. represents a single plate of molecules.

Fig. 10 represents a double plate.

(36.) When the added plates successively envelope the whole of a smaller Crystal, its original form is preserved through every increase of size, as is shown in fig. 11, representing a square prism which has increased in magnitude without change of form. When the additions do not cover the whole surface of a primary plane, but there are rows of molecules omitted on the edges, or angles of the superimposed plates, such omission is called *a decrement*; because the primary form on which the diminished plates are successively laid, appears to decrease, as it were, on the edge or angle on which such omissions take place.

(37.) *Decrements* are said to begin at, or to set out from, the particular edge or angle at which the omission of molecules first takes place; and to proceed along that plane on which the defective plates of molecules are laid; and they are said to take place either in breadth or in height.

Decrements in breadth are those which result from the reduction of the superficial area of the superimposed plate, by the abstraction of rows of molecules from its edges or angles.

Decrements in height relate to the thickness of the plate from which the abstraction of rows of molecules takes place.

Decrements are divided into two principal classes, *simple* and *intermediary*.

(38.) *Simple decrements* are those in which one or more rows, in breadth, are abstracted from plates of one or more molecules in thickness.

Fig. 12 exhibits a simple decrement by one row in breadth on the edge *c d* of the primary form.

Fig. 13 exhibits a simple decrement by one row in breadth on the angle *c* of the primary form.

For the sake of rendering the expression *rows of molecules* generally applicable to decrements both on the angles and edges of a primary form, the term *row* is applied to express the *single molecule* first abstracted from the *angle* of any plate.

In fig. 14 the single molecule *a b* is regarded as the *first row* to be abstracted from the angle of the imaginary plate; the two molecules *c, d* as the *second row*; the three molecules *e, f* as the *third row*, and so on.

Fig. 15 shows a simple decrement by two rows in height on the edge *c d* of the primary form.

Fig. 16 shows a simple decrement by two rows in height on an angle of the primary form.

It is observable in these figures, that each successive plate is less by one row of molecules than the plate on which it rests. It is by this continual recession of the edges of the added plates, that the Crystal appears to decrease on its edges or angles, and that new planes are produced. The edges of the new planes which would be produced by the four preceding decrements, are shown by the lines *a b c d*, fig. 12 and 15, and by the lines *a b c*, fig. 13 and 16.

When the numbers of molecules in height and breadth are different, the nature of the decrement is expressed by a fraction, of which the *numerator*, or *upper figure*, denotes the *number of molecules in breadth*, and the *denominator*, or *lower figure*, the *number in height*; thus a decrement denoted by $\frac{1}{2}$ would imply an abstraction of a single row from a plate of two molecules in thickness, and one denoted by $\frac{4}{3}$ an abstraction of four molecules in breadth and three in height.

(39.) *Intermediary decrements* affect only the solid angles of Crystals, and may be conceived to consist in the abstraction of rows of small masses of molecules from the successively superimposed plates, each mass, or as it may be termed, *compound molecule*, containing unequal numbers of single molecules in length, breadth, and height. Thus if we suppose the compound molecule abstracted in an intermediary decrement to belong to a single plate, it must consist of some other numbers of molecules in the directions *d* and *e*, fig. 17 and 18.

In fig. 17 the compound molecule consists of a single molecule in height, two on the edge *d*, and three on the edge *e*, producing the new plane *a b c*.

Fig. 18 exhibits an intermediary decrement in which the compound molecule consists of three single molecules in height, four on the edge *d*, and two on the edge *e*, producing the new plane *a b c*.

It may be remarked, that the planes produced by simple decrements intersect one or more of the primary planes in lines parallel to one of their edges or diagonals. The term intermediary has been used, because the line at which the secondary plane thus produced intersects a primary plane, is never parallel to either an edge or diagonal of that plane, but is an intermediate line between them, as may be observed by comparing the figures.

(40.) The new planes produced by decrements are denominated *modifying* or *secondary planes*, and the primary form, when altered in shape by the interference of such planes, is said to be *modified* on the edges or angles on which they have been produced. And such edges or angles are also said to be *replaced* by the secondary planes.

(41.) The *law* of a decrement, or, as it is sometimes expressed, of a plane, is a term used to denote the numbers of molecules in height and breadth abstracted from *each* of the superimposed plates, in the production of such plane.

(42.) It is evident from an inspection of the preceding figures that the effect of any decrement upon the primary form is similar to that which would take place if the enlarged Crystal had been first completed, and then the whole of the omitted molecules removed from it in one mass.

This mass, being all the addition to the secondary form which would be required to complete the primary, will be termed *the defect* of the primary form. And it is obvious from the preceding figures that the primary edges of this *defect* must be composed of edges of molecules respectively proportional to the numbers which express the law of decrement.

Thus in fig. 13 each edge of the defect would consist of the edges of three molecules, and these being respectively divided by 3 correspond to a decrement by one row.

The edge of the defect of fig. 15 corresponding to the lateral edge of the prism must consist of four molecules, and the edge corresponding to the terminal edge of the prism of two molecules; which numbers agree with the law of decrement, the proportion of 4 to 2 being the same as that of 2 to 1.

This theory of decrements, as it will be afterwards seen, is introduced for the purpose of rendering the explanations of the manner in which the secondary forms of Crystals may be conceived to be produced more distinct.

(43.) When an edge, or solid angle, is replaced by one plane, it is said to be *truncated*. When an edge is replaced by two planes, which respectively incline on the adjacent primary planes at equal angles, it is *bevelled*.

(44.) If any secondary plane replacing an edge, and being parallel to it, incline equally on the two adjacent primary planes, or if replacing a solid angle, it incline equally on all the adjacent primary planes, it is called a *tangent plane*.

Of the Goniometer.

(45.) The instruments used for measuring the angles at which the planes of Crystals incline to each other, are called Goniometers.

(46.) The mutual inclination of any two planes, as of *a* and *b*, fig. 19, is indicated by the angle formed by two lines *e d*, *e f*, drawn upon them from any point *e* on the edge at which they meet, and perpendicular to that edge.

Now it is known that if two right lines, as *g f*, *d h*, fig. 20, cross each other at any point *e*, the opposite angles *d e f*, *g e h* are equal.

If, therefore, the lines *g f*, *d h* are supposed to be very thin and narrow plates, and to be attached together by a pin at *e*, serving as an axis to permit the point *f* to be brought nearer either to *d*, or to *h*; and that the edges *e d*, *e f*, of those plates, are applied to the planes of the Crystal, fig. 19, so as to rest upon the lines *e d*, *e f*, it is obvious that the angle *g e h* of the movable plates would be exactly equal to the angle *d e f* of the Crystal.

(47.) The *common* Goniometer is a small instrument for measuring this angle *g e h* of the movable plates. It consists of a semicircle, fig. 22, divided into 360 equal parts, or half degrees, and a pair of movable arms *d h*, *g f*, fig. 21. The semicircle having a pin at *i*, which fits into a hole in the movable arms at *e*.

The method of using this instrument is, to apply the edges *d e*, *e f* of the movable arms to the two adjacent planes of any Crystal, so that they shall accurately touch or rest upon those planes *in directions perpendicular to their edge*. The arm *d h* is then to be laid on the plate *m n* of the semicircle, fig. 22, the hole at *e* being suffered to drop on the pin at *i*, and the edge nearest to *h* of the arm *g e* will then indicate on the semicircle, as in fig. 23, the number of degrees which the measured angle contains.

When this instrument is applied to the planes of a Crystal, the points *d* and *f*, fig. 21, should be previously

brought sufficiently near together for the edges $d\,e$, $e\,f$, to form a more acute angle than that about to be measured. The edges being then gently pressed upon the Crystal, the points d and f will be gradually separated, until the edges coincide so accurately with the planes that no light can be perceived between them.

The *common* Goniometer is, however, incapable of affording very precise results, owing to the occasional imperfection of the planes of Crystals, their frequent minuteness, and the difficulty of applying the instrument with the requisite degree of precision.

(48.) The more perfect instrument, and one of the highest value to Crystallography, is the *reflective* Goniometer, invented by Dr. Wollaston, which will give the inclination of planes whose area is less than $\frac{1}{10000}$ of an inch, to less than a minute of a degree.

This instrument has been less resorted to than might, from its importance to the Science, have been expected, owing, perhaps, to an opinion of its use being attended with some difficulty. But the observance of a few simple rules will render its application easy.

The principle of the instrument may be thus explained.

Let $a\,b\,c$, fig. 21, represent a Crystal, of which one plane only is visible in the figure, attached to a circle, graduated on its edge, and movable on its axis at o; and let a and b mark the position of the two planes whose mutual inclination is required.

And let the lines $o\,e$, $o\,g$, represent imaginary lines resting on those planes in directions perpendicular to their common edge, and the dots at i and h to be some permanent marks in a line with the centre o.

Let the circle be in such a position that the line $o\,c$ would pass through the dot at h, if extended in that direction, as in fig. 24.

If the circle now be turned round with its attached Crystal, as in fig. 25, until the imaginary line $o\,g$ is brought into the position of the line $o\,c$ in fig. 24, the number 120 will stand opposite the dot at i.

This is the number of degrees at which the planes a and b incline to each other. For if the line $o\,g$ be extended in the direction $o\,i$, as in fig. 25, it is obvious that the lines $o\,e$, $o\,i$, which are perpendicular to the common edge of the planes a and b, would intercept exactly 120° of the circle.

Hence an instrument constructed upon the principle of these diagrams, is capable of giving with accuracy the mutual inclination of any two planes which reflect objects with sufficient distinctness, if the means can be found for placing them successively in the relative positions shown in the two preceding figures.

(49.) This purpose is effected by causing an object, as the line at m, fig. 26, to be reflected successively from the two planes a and b, at the same angle.

It is well known that the images of objects are reflected from bright planes at the same angle as that at which their rays fall on those planes; and that when the image of an object reflected from a horizontal plane is observed, it appears as much below the reflecting surface as the object itself is above it.

If therefore the planes a and b, fig. 26, are successively brought into such positions, as will cause the reflection of the line at m, from each plane, to appear to coincide with another line at n, both planes will be successively placed in the relative positions of the corresponding planes in fig. 24 and 25.

To bring the planes of any Crystal successively into these relative positions, the following directions will be found useful.

(50.) The instrument, as shown in the sketch, fig. 27, should be first placed on a pyramidal stand, and the stand on a small steady table, about six to ten or twelve feet from a flat window.

The graduated circular plate should stand perpendicularly from the window, the pin x being horizontal, not in the direction of the axis as it is usually figured, but with the slit end nearest to the eye.

Place the Crystal which is to be measured on the table, resting on one of the two planes whose inclination is required, and with the edge at which those planes meet, nearest and parallel to the window.

Attach a portion of wax, about the size of d, to one side of a small brass plate e, fig. 28; lay the plate on the table with the edge f parallel to the window, the side to which the wax is attached being uppermost, and press the end of the wax against the Crystal until it adheres; then lift the plate with its attached Crystal, and place it in the slit of the pin x, with that side uppermost which rested on the table.

Bring the eye now so near the Crystal as, without perceiving the Crystal itself, to permit the images of objects reflected from its planes to be distinctly observed, and raise or lower that end of the pin x which has the small circular plate on it, until one of the horizontal upper bars of the window is seen reflected from the upper or first plane of the Crystal, corresponding with plane a, fig. 21, and until the image of the bar appears to touch some line below the window, as the edge of the skirting board where it joins the floor.

Turn the pin x on its own axis also, if necessary, until the reflected image of the bar of the window coincides accurately with the observed line below the window.

Turn now the *small* circular handle a on its axis, until the same bar of the window appears reflected from the second plane of the Crystal corresponding with plane b, fig. 24 and 25, and until it appears to touch the line below; and having, in adjusting the *first* plane, turned the pin x *on its axis* to bring the reflected image of the bar of the window to coincide accurately with the line below, *now move the lower end of the pin laterally*, either towards or from the instrument, in order to make the image of the same bar, reflected from the *second* plane, coincide with the same line below.

Having ascertained by repeatedly looking at and adjusting both planes, that the image of the horizontal bar, reflected successively from each, coincides with the observed lower line, the Crystal may be considered ready for measurement.

Let the 180° on the graduated circle be now brought opposite the 0 of the vernier at c, by turning the handle b; and while the circle is retained accurately in this position, bring the reflected image of the bar from the *first* plane to coincide with the line below, by turning the *small* circular handle a. Now turn the graduated circle, by means of the handle b, until the image of the bar reflected from the *second* plane is also observed to coincide with the same line below. In this state of the instrument the vernier at c will indicate the degrees and minutes at which the two planes incline to each other.

The accuracy of the measurements taken with this instrument will depend upon the precision with which the image of the bar reflected successively from both planes is made to appear to coincide with the same line

below: and also upon the 0, or the 180°, on the graduated circle, being made to stand precisely even with the lower line of the vernier when the first plane of the Crystal is adjusted for measurement.

A wire being placed horizontally between two upper bars of the window, and a black line of the same thickness being drawn parallel to it below the window, will contribute to the exactness of the measurement, by being used instead of the bar of the window and any other line.

Persons beginning to use this instrument, are recommended to apply it first to the measurement of fragments at least as large as that represented in fig. 28, and of some substance whose planes are bright. Crystals of carbonate of lime will supply good fragments for this purpose, if they are merely broken by a slight blow of a small hammer.

For accurate measurement, however, the fragments ought not, when the planes are bright, to exceed the size of that shown in fig. 27. And they ought to be so placed on the instrument, that a line passing through its axis should also pass through the centre of the minute fragment which is to be measured. This position on the instrument ought also to be attended to when the fragments or Crystals are large. In which case the common edge of the two planes whose inclination is required, should be brought very nearly to coincide with the axis of the Goniometer; and it is frequently useful to blacken the whole of the planes to be measured, except a narrow stripe on each close to the edge over which the measurement is to be taken.

Of the Origin and Progress of Crystallography, and of the different Systems which have been formed for explaining the Relations of Primary and Secondary Forms.

(51.) It does not appear that this Science was even known to the Ancients, or that the few crystalline forms with which they were acquainted were otherwise regarded by them than as mere accidental figures.

Linnæus was the first who bestowed any particular attention upon this subject.

Among the numerous observed forms of Crystals, there are some which belong only to particular minerals, and others which are common to different species. Thus the cube occurs as a form of fluate of lime and of galena. The regular octahedron as that of alum, the diamond, and the ruby.

Observing that the form of the octahedron was common to the diamond and to alum, Linnæus conceived that the salts were in some manner the generators of the forms of Crystals, and that a mineral which agreed with a salt in its form, might in regard to form be considered a subspecies of that salt. Hence the diamond was denominated alum diamond, and a remote analogy was imagined to exist between his systems of Crystallography and Botany.

This author appears to be the first who published figures of Crystals, and he is regarded by Haüy, from whom we have extracted many of these preliminary observations, as the founder of the Science of Crystallography.

This title is, however, more justly due to Romé de l'Isle, who made the first extensive collection of Crystals, and was the first to arrange together those belonging to each known species of mineral; and having selected from each group so arranged some simple figure, as the fundamental or derivative form from which the remainder might be produced by *cutting away* its edges and angles, he reduced all the forms belonging to each set into a connected series; and he thus exhibited for the first time an outline of the relations of crystalline forms to each other.

He also published figures of the Crystals he had observed, with the measurements of many of their angles, from which it appeared that the corresponding planes on all the Crystals belonging to the same species of mineral, inclined to each other at the same angle; this, it is evident, was an important step in the progress of the Science of which we are about to treat.

As the subject was new in his hands, the labour of arranging and analyzing all the forms he had observed, and measuring their angles, must have been very considerable. The want, however, of instruments well adapted to measure the angles of Crystals with accuracy, exposed him, as might have been expected, to numerous errors, which have been corrected by later observations.

Werner, to whose persevering industry Mineralogy is so much indebted, also invented a method of describing Crystals by reference to certain fundamental forms.

His method, however, although it might be applied to simple and regular figures, will be found too cumbrous for the description of such as are contained under numerous planes. We may refer such of our readers as desire to know more of this nearly obsolete system to Brochant's *Traité Elémentaire de Minéralogie*, Paris, 1808; or to the second edition of Professor Jameson's *Mineralogy*.

The preceding methods, it may be observed, are merely descriptive, and relate simply to the forms of Crystals, without reference to any theory of structure, or to any laws by which the relations of the observed varieties of form might be explained. No attempt is made to ascertain the cause of the constancy of the angles of inclination of corresponding planes of Crystals belonging to the same mineral, nor do these methods provide any means of determining, *à priori*, the forms under which any species of mineral may present itself, from a knowledge of its simple fundamental Crystal.

(52.) Bergman was the first who attempted to penetrate into the interior structure of Crystals, and to refer their observed variations of form to the superposition or plates of crystalline matter upon the planes of a fundamental solid; these plates being sometimes constant in figure, and sometimes variable.

This theory was supported by the fractures of one of the Crystals of carbonate of lime, known in this Country by the name of dog-tooth spar, contained within twelve scalene triangular planes, and forming a bi-pyramidal figure. One of these Crystals may be easily split so as to exhibit only the six planes of a rhomboid, which was in theory conceived by Bergman to represent the nucleus, or basis, upon which the twelve-sided figure had been constructed. But Bergman did not pursue the inquiry upon which he had thus successfully entered. He neither determined the nature of his crystalline plates, nor the forms of the particles of which they might be conceived to be composed, nor the laws connected with their variable character.

Nearly at the time, however, that Bergman was engaged in these researches, Crystallography occupied the zealous attention of Haüy, whose investigations embraced the forms and dimensions of the molecules of which these plates might be composed, and who was

thus led to a strict demonstration of the laws which might govern their arrangement; and thus for the first time Crystallography assumed the character of a regular Science.

His theory is founded upon a supposition that all the crystalline forms which are presented by any single species of mineral, and which are known sometimes to be numerous, are related to some simple form, which may be regarded as a general type of all the known Crystals belonging to the species.

This simple form is conceived to be composed of particles either similar in figure to itself, or bearing some known and constant relation to that figure. It is also supposed to be contained, as an *inscribed solid*, within all the Crystals which differ from it in external figure, and the observed differences of external figure are supposed to depend upon the laws according to which the added particles arrange themselves about the contained solid.

To render this theory consistent with the observed facts, it is obvious that the form which is adopted as the type of the species should not be chosen arbitrarily, and that the assumed laws of arrangement of the enveloping particles should be capable of precise and rigorous demonstration.

The method adopted by Haüy to develope this type or fundamental form, was by splitting or cleaving the Crystal, and he was induced from the following considerations to conclude, that this fundamental form might always be so derived.

A Crystal of carbonate of lime presenting the form of a regular hexagonal prism, had been broken from a group of similar prisms. On examining it he observed that the fractured surface exposed by its detachment from the group was a bright plane, and on more narrowly inspecting this fracture he observed that a terminal edge of the prism had been removed by it.

On perceiving this, he attempted to remove all the terminal edges by analogous fractures, but he found that only the alternate three of the six edges which terminate a prism of that form, could be so displaced.

The fig. 29 exhibits the directions of the three cleavage planes at each extremity of the prism; the three below being severally parallel to the three above.

By continuing to cleave this Crystal parallel to all the newly developed planes, the faces of the hexagonal prism were observed successively to disappear, and when they were at length entirely removed, a new solid remained which was an obtuse rhomboid.

The fig. 30 exhibits the rhomboid in the interior of the hexagonal prism.

The idea which this fact suggested to Haüy's mind was, that all the Crystals of carbonate of lime, whatever might be their external form, might possibly contain similar rhomboids; yet it was difficult at first to conceive how this particular solid should be the nucleus of more acute and more obtuse rhomboids which occur among the Crystals of this substance.

Experiment, however, proved, that this particular rhomboid did exist in a symmetrical position in each of those forms which differed from it externally; the only point to be attended to in developing the nucleus being the direction of the necessary cleavage. This may generally be perceived by looking through the Crystal when exposed to a strong light; or it may be ascertained by slightly fracturing a terminal edge or angle. Haüy states, that all other mineral substances, when submitted to mechanical division, have afforded analogous proofs of the generality of this result; a statement however not strictly correct, as there are several minerals which do not admit of being cleaved into regular solids, and others from which two or more different solids may be obtained by cleavage.

The forms of the solids thus obtained by mechanical division he terms *primitive*, upon the supposition of their corresponding in figure with the original minute solid upon which the Crystal was first formed.

But the production in many instances of several solids from the same Crystal by cleavage, and the impossibility in others of producing any solid by that process; the inconsistency of admitting several primitive forms of the same mineral, and the impossibility of producing any such primitive form when there are not cleavages in at least three directions; have induced us to abandon altogether the notion of a *primitive* solid, and to distinguish this original or parent figure by the term *primary form*, denoting simply its relative character to the secondary forms derived from it.

From the mechanical division to which many Crystals may be subjected, Haüy was led to the conclusion that every Crystal was from its centre to its surface an assemblage of molecules symmetrically disposed; and although his views of its structure regarded a certain portion of its mass as an imaginary nucleus, or elementary solid, upon which subsequent increments had taken place, the existence of this nucleus is assumed only as a theoretic basis for calculating and demonstrating the laws according to which all the varieties of crystalline forms related to it might be produced.

Haüy's theory next supposes that nature has set limits to the angles at which the primary planes of Crystals incline to each other; a supposition which does not appear to be supported by a single fact. The circumstance which led him to this conjecture was an inaccurate measurement of the Crystal of carbonate of lime, which afforded the first clue to his theory of the structure of Crystals; an inaccuracy occasioned by the unfitness of the instrument he employed to measure Crystals with exactness.

We have not in this Treatise followed Haüy in classing and naming Crystals, but have adopted and generalized a method of description first introduced by Bournon.

By a reference to any of his descriptions of minerals in the *Transactions of the Geological Society*, or to Bournon's *Treatise on Carbonate of Lime*, it will be seen that he has arranged and numbered all those individual modifications of the primary form of the mineral described, which had been found to occur among its secondary forms. Our proceeding has been to reduce into classes in the tables of modifications not only all the *observed* modifications of Crystals, but *all the modifications of which each particular primary form is susceptible while influenced by the laws of symmetry.* Thus presenting to the reader not merely the series of known forms, but the entire system of possible forms which can result from regular Crystallization; and hence every new form which may be discovered, if it be conformable to those laws, will be found among those presented by our tables.

(53.) Within a few years two new systems of Crystallography have been produced in Germany. One by Professor Weiss, and the other by Professor Mohs, now of Vienna.

Crystallography.

These systems differ from each other in notation and in some other points, but they agree in using the axes of Crystals to express the relations of the secondary to the primary forms.

The following statement exhibits the relations of the four systems of primitive forms of Professor Mohs to our classes of primary forms.

Mohs's systems	*consists of the*	
1. The rhombohedral......	rhomboid.	
2. The pyramidal.........	square prism.	
3. The prismatic	right rhombic / oblique rhombic / doubly oblique	prisms.
4. The tessular	cube.	

The reader who may be desirous of seeing more of this very uninviting system, both in notation and nomenclature, will find it developed in a Work on Mineralogy published in this Country by Mr. Haidinger, an able and intelligent pupil of Mohs.

Of the Molecules of Crystals.

(54.) The Molecules which are aggregated together in the production of Crystals, are, as already stated, conceived to be minute homogeneous solids contained within symmetrically-disposed plane surfaces. And they are also supposed to differ in figure in the different classes of primary forms.

(55.) If we attempt to fracture a piece of galena, it will split into rectangular fragments. But as the primary Crystal of galena is a cube, it is assumed, that if the rectangular fragments could be reduced to single Molecules, those Molecules would be cubes.

(56.) If a Crystal of carbonate of lime be reduced to fragments, it is found that their planes, however minute, incline to each other at angles respectively equal to those of the primary rhomboid. It is therefore inferred that the Molecule of carbonate of lime is a minute rhomboid, similar to the primary form.

(57.) The primary form of sulphate of barytes has been ascertained from cleavage, and from its secondary planes, to be a right rhombic prism. This prism may be split into smaller right rhombic prisms, whose angles are respectively equal to those of the primary Crystal. It is therefore supposed that the primary Crystal and the Molecules of this substance are similar prisms.

Some other classes of parallelopipeds may also be split into fragments, resembling in their angular measurement the primary solids from which they have been detached, and it is hence inferred generally that the primary forms and their respective Molecules are similar solids.

(58.) In several instances, however, cleavage does not produce this primary solid.

A cube of fluate of lime, for example, does not yield that figure by cleavage, but, as will be shown in the section on cleavage, it will split into regular octahedrons, or tetrahedrons, or rhomboids whose plane angles are 60° and 120°.

Haüy has assumed the octahedron as the *primitive* form of this mineral, and has regarded the tetrahedron as the Molecule of the octahedral Crystal, upon which supposition the octahedron must be composed of tetrahedral solids united by their points, leaving octahedral spaces; and he has also supposed that the tetrahedron, when that is the predominating, and in his view, the primitive form, is constituted of tetrahedral Molecules and octahedral spaces.

Of the Molecules of Crystals.

The rhombic dodecahedron may be cleaved into obtuse rhomboids, obtuse octahedrons, and irregular tetrahedrons, as will be shown in the section on cleavage. Of these, Haüy has selected the irregular tetrahedron for the Molecule of the dodecahedron, and has supposed that the decrements on this form are produced by the abstraction, not of single Molecules, but of several of these combined in the figure of those obtuse rhomboids which are produced from it by cleavage.

The very complicated view of the structure of the octahedron and dodecahedron, which Haüy has thus introduced into his theory of Crystals, and the apparent improbability that the Molecules of the cube, the regular octahedron, tetrahedron, and dodecahedron, among whose primary and secondary forms so perfect an indentity subsists, should really differ from each other, have induced us to conclude that they are similar, and that the common Molecule is a cube.

(59.) This theory of cubic Molecules may be reconciled with the cleavages which take place parallel to the primary planes of the tetrahedron, the octahedron, and the rhombic dodecahedron, as well as to those of the cube, by supposing the Molecules capable of being held together with different degrees of attractive force in different directions. When this attraction is least in a direction perpendicular to the planes of the Molecules, they will be most easily separated at their surfaces by cleavage.

When the attraction is least in the direction of the oblique axis of the Molecules, they will be the most easily separated in that direction, and the octahedron or tetrahedron will be the result of cleavage.

And if the attraction be least in the direction of their diagonal planes, a rhombic dodecahedron will be the solid produced by cleavage.

This supposition of a greater or less degree of molecular attraction in one direction of the Molecule than in another, is not inconsistent with many well-known facts in Crystallography; and it is possible to conceive that the nature, the number, and the particular forms of the *elementary* particles, which enter into the composition of these three kinds of cubic Molecules, may so vary, as to produce the variety of character which is here supposed to exist.

The primary form both of corundum and of carbonate of lime is a rhomboid; and the Crystals of these substances may be cleaved parallel to their primary planes, the carbonate of lime yielding much more readily to cleavage than the corundum. But the corundum has also a cleavage perpendicular to its axis, which does not exist in carbonate of lime, and which would expose the terminal solid angles of the contiguous Molecules. It may therefore be inferred from this transverse cleavage that the molecular attraction is comparatively less in the direction of the axis of the Molecules of corundum, than it is in those of carbonate of lime. And from the greater adhesion of the planes of corundum, than of those of carbonate of lime, it is inferred that the attraction is comparatively greater between the planes of the Molecules of the corundum, than between those of carbonate of lime.

While, however, we thus attempt to reason concerning Molecules, it must not be forgotten that the whole theory of decrements and Molecules is to be regarded

only as the foundation of a method of demonstrating the relations of Crystals, and of constructing descriptive characters, by which those relations may be expressed.

It must also be admitted that we possess no certain knowledge relative to the figures of the ultimate particles of matter. They have been supposed by some to be minute spheres or spheroids, but whether they are plane or curvilinear solids, they present anomalies when in particular states of combination which have not been hitherto explained.

The crystalline form of native silver is a cube, and its Molecules are therefore supposed to be cubes.

The *natural* crystalline forms of sulphur may be referred to a right rhombic prism as the primary, and which is therefore assumed to be the form of the Molecules. Yet the form of the compound of sulphur and silver is a cube.

Now whether the Molecules be possessed of plane or curved surfaces, it is difficult to suppose that the cube of silver and the rhombic prism of sulphur should both be composed of Molecules which are similar in form. And if they are not similar, it is equally difficult to account for the compound of silver and sulphur assuming the form of a cube.

We have in the two crystalline forms of iron pyrites (composed of iron and sulphur) an example of a cube and a right rhombic prism being both produced by the same chemical compound; and it is also found that sulphur itself will assume two different forms, according to the circumstances under which the Crystallization takes place. The cause, however, of this dimorphous character of some substances is not at all understood.

Of the Structure of Crystals.

(60.) It has been already stated that Crystals are conceived to increase in magnitude by the continual addition of plates of molecules to their surfaces.

The *Structure* of Crystals, *or the order in which these molecules are arranged*, may be illustrated by an experiment with common salt. If a portion of this salt be dissolved in water, and the water be allowed to evaporate slowly, rectangular Crystals will be deposited on the sides and bottom of the vessel. These will at first be very minute, but they will increase in size as the evaporation proceeds; and if the quantity of salt dissolved be sufficient, they will at length attain a considerable magnitude.

If the edge of a knife be applied to the surface of any one of these Crystals in a direction parallel to one of its edges, as at *a b*, fig. 32, the Crystal may, by a slight blow, be cleaved parallel to one of its sides.

If a knife be applied in the same manner successively to the other lines *c d*, *e f*, *g h*, and to the other surfaces of the Crystal, so that its edge be parallel in each instance to the edge of the Crystal, it will be found that there are cleavages parallel to all the planes of the rectangular solid; and the plates which have been removed by these cleavages may be also subdivided into smaller solids of the same character.

It is hence inferred that the molecules of Crystals are so arranged as to form plates in the direction of all the primary planes, as shown in fig. 11. And that in common salt the molecular attraction is least between the surfaces of the molecules.

This regular Structure is supposed to belong to all regularly crystallized bodies, although in many instances it cannot be manifested by cleavage.

(61.) It frequently happens that the regular Crystallization of bodies has been prevented by some disturbing cause which has interfered with that orderly arrangement of the molecules necessary to the constitution of perfect crystalline structure; in this case the crystalline mass will be curved or otherwise irregular, or from the minuteness of the separate Crystals and their variety of position it may present a granular character. This granular character would be produced if the solution we have supposed of common salt were rapidly evaporated and suddenly cooled.

Of Cleavage.

(62.) The Cleavage of Crystals is sometimes an important mineralogical character.

The direction in which the Cleavage of a Crystal lies may frequently be perceived by turning the Crystal round in a strong light, although it cannot be readily cleaved in that direction.

(63.) When a Crystal may be cleaved parallel to the primary planes, and also in other directions, it is said to have two or more *sets* of Cleavages. Those which are parallel to the planes of the primary form, are called the primary set, and those which are not parallel to those planes, are termed supernumerary sets.

The oxide of tin, described by Mr. Phillips in the *Geological Transactions*, has three sets of cleavages; one parallel to the planes of an obtuse octahedron with a square base, and two others perpendicular to that base and parallel to its edges and diagonals.

Different specimens of the same substance will occasionally yield to the knife or hammer with different degrees of facility; and even carbonate of lime, which in general splits with ease and regularity, will sometimes present a conchoidal fracture.

(64.) Some practice is necessary in order to cleave minerals neatly, and some little experience in the choice of the instruments to be used.

In many instances, the mineral being placed on a small anvil of iron or lead, a blow with a hammer will be sufficient for dividing it in the direction of its cleavage planes; and sometimes a knife or small chisel may be applied in the direction of those planes, and pressed with the hand, or struck with a light hammer, or the Crystal may be held in the hand, and split with a small knife; or it may be split by means of a pair of small cutting pincers with *parallel edges*; and a small short chisel, fixed with its edge outward in a block of wood, is sometimes a convenient instrument for resting the mineral to be cleaved upon.

(65.) When all the planes of a primary form are similar, as those of the cube and rhomboid, the primary Cleavages may be effected with equal facility in all directions, and the cleavage planes are all similar in lustre and general character. This may be illustrated by cleaving galena and carbonate of lime.

But where the planes of a primary form are not all similar, as in all prisms, the primary Cleavages are rarely effected with equal facility in the directions of the dissimilar planes, nor do the cleavage planes agree in their general characters. Hence the cleavage planes of a mineral may occasionally prove that it does not belong to a particular class of primary forms, although the

Cleavage alone is not, in all cases, sufficient to determine what the primary form really is.

Felspar, kyanite, and sulphate of lime, afford instances of the greater facility with which a Cleavage takes place in one or two directions than in any other.

(66.) There are among minerals some substances which yield readily to mechanical division in one or two directions, but do not admit of distinct Cleavage in a third direction, so as to produce an entire solid.

This circumstance has introduced into Mineralogy the terms *single, double, triple, quadruple, and sextuple* Cleavage, which are not to be confounded with the primary and supernumerary *sets* of Cleavages before alluded to.

When a mineral can be split in *only one direction*, the Cleavage is said to be *single;* when in *two* directions, which may be conceived to give four sides of a prism, it has a *double* Cleavage; when there is a Cleavage in *three* directions, such as to produce a solid bounded by six planes, which are parallel when taken two and two, it is termed a *triple* Cleavage.

A *quadruple* Cleavage, or one in *four* directions, will produce a tetrahedron, an octahedron, or an entire hexagonal prism.

The rhombic dodecahedron being contained within *six* pairs of parallel planes lying in different directions, is produced by a *sextuple* Cleavage.

Supernumerary Cleavages either alone, or combined with the primary, may produce solids contained under greater numbers of planes.

In the preceding sections on molecules and structure, some of the results of Cleavage have been noticed. The subject, however, requires to be further illustrated.

(67.) A cube of fluate of lime does not split in directions parallel to its planes as galena does, but splits obliquely. Let fig. 33 represent a cube of this mineral.

If the edge of a knife be applied to the diagonal line *a b* of this cube, and the knife inclined in the direction of *e*, the solid angle *a b e c* may be removed.

If the edge of the knife be again applied to the same line *a b*, and struck in the direction of *f*, another solid angle *a b f d* may be removed, and applying the knife in the direction of the line *c d*, two other solid angles *a* and *b* may be detached.

The new solid produced by these Cleavages is represented by fig. 34.

If the knife be applied successively to the lines *i k*, *k l*, *l m*, *m i*, fig. 34, and struck in the direction of *n*, the remaining solid angles of the cube may be removed, and the regular octahedron *i k l m n o* will be produced.

It is apparent that the solid angles of this octahedron must touch the middle points of the planes of the cube, its position in which is shown by fig. 35.

This octahedron may be further cleaved in a direction parallel to its own planes.

If it be cleaved parallel to six only of its planes, omitting any two parallel ones, and the Cleavage be continued until only the central points of the two parallel ones remain, a figure of six sides will be produced.

This figure is a rhomboid whose plane angles are 60° and 120°.

Fig. 36 shows the position of this rhomboid in the octahedron, from which it is evident that the Cleavage which produces it must be continued as far as the lines *i k*, *l m*, *n o*, and to those which are parallel to them on the opposite plane.

Fig. 37 exhibits the same rhomboid separately, and it may be regarded as an octahedron with two of its planes covered by small tetrahedrons, *p f r s* and *t u x*. These tetrahedrons are supposed to consist of masses of cubic molecules, and by their removal, as in fig. 38, a perfect octahedron will be reproduced.

If an octahedron be cleaved parallel to any four *alternate* planes, fig. 39, the Cleavage be continued until only the central points of the other four planes remain, a regular tetrahedron will be produced, as shown by the interior lines.

The tetrahedron thus obtained, fig. 40, may be regarded as an octahedron, four of whose planes are concealed, or covered by smaller tetrahedrons, *p q r s*, *p q u t*, *u q x v*, *q x r y*, and by the removal of these it may be reduced to a perfect octahedron.

The tetrahedron and octahedron have thus obviously the same set of Cleavages, and the octahedron may be regarded as an imperfect tetrahedron, requiring certain additions to complete that form.

(68.) A cube of blende will split in directions parallel only to its diagonal planes. These Cleavages will truncate the edges of the cube, and if continued until all the edges are removed, and the faces of the cube disappear, a rhombic dodecahedron will be produced.

Fig. 41 shows the position of the rhombic dodecahedron in the cube, in which six of its solid angles touch the middle points of the planes of the cube.

If this dodecahedron, fig. 42, be cleaved parallel to the planes *a, d, i, m*, and to the four planes parallel to these, until the four remaining planes of the dodecahedron disappear, an obtuse octahedron will be produced.

Fig. 43 exhibits this octahedron separately, the planes being marked by the same letters as appear on the corresponding planes of the dodecahedron.

If the Cleavage be effected parallel only to the planes *a, d, e*, and those parallel to them, until the other primary planes disappear, an obtuse rhomboid will result, as seen in fig. 44; this rhomboid measures 120° over the edges at which the planes *a* and *e* meet.

If the Cleavage takes place parallel to any four *alternate* planes of the obtuse octahedron, and be continued until the four cleavage planes alone remain, an irregular tetrahedron, fig. 45, will be produced, whose planes meet at an angle of 90° at the edges, *n o*, *p q*, and at an angle of 60° at the other edges.

The ultimate relation of the tetrahedron to the octahedron in reference to the theory of cubic molecules, may be explained in the following manner.

Let fig. 47 represent the smallest octahedron that can be imagined to exist, formed of seven cubic molecules, and let fig. 46 represent a tetrahedron containing this minute octahedron. The tetrahedron would obviously be reducible to the octahedron, as other tetrahedrons are, by the removal of all its solid angles. But it is apparent that the solid angles to be removed in this instance, are the small cubes *a, e, g, i*, and on their removal the octahedral solid, shown in fig. 47, will remain.

This octahedron is supposed to rest on one of its planes, and the molecules *b c*, *c h*, *f c*, *c d*, may be conceived to constitute four of its edges.

In a similar manner the compatibility of the cubic molecule with the solids, obtained by Cleavage from the rhombic dodecahedron, might be easily shown.

Of Decrements, and the Characters of the Secondary Planes produced by them.

(69.) The explanation already given of the manner in which new planes modifying the primary forms may be conceived to be produced by the operation of different laws of Decrement, has been limited to the effect produced upon only a single edge or angle of the primary form. When similar edges or angles are all operated upon at the same time by any given Decrement, a new figure is produced.

The square prism has all its terminal edges similar, and all its terminal angles also similar, and, consequently, when one of those edges or angles is affected by any Decrement, they will generally all be so.

The upper part of fig. 48 will explain the manner in which a Decrement by one row of molecules on the terminal edges of a square prism, is conceived to produce a set of planes corresponding to those marked *c* of the tables of modifications. The lower part of the figure represents the ordinary character of the terminal planes of a square prism so modified.

The upper part of fig. 49 exhibits the effect of a Decrement by one row of molecules on the terminal angles of a square prism, producing a secondary form corresponding to the planes *a* of the modifications of that figure. The lower part presents the ordinary appearance of a square prism so modified.

(70.) The causes which occasion Decrements do not appear to be understood; Crystals so minute as to be seen only by the aid of a microscope, are found variously modified; hence the circumstance, whatever it may be, which occasions the modification, begins to operate very soon after the Crystal has been formed. Perhaps it may influence the arrangement of the first few molecules which are capable of producing a modified form; and as Crystals, during their increase in magnitude, sometimes undergo a change of form by the extinction of some modifying planes, or the production of others, the cause which occasions a Decrement may be suspended, or may be first brought into operation at any period during the increase of a Crystal in size.

For the purpose of affording a clearer illustration of the theory of Decrements, it has been found convenient to imagine that the primary form of any modified Crystal had attained such a magnitude before the law of Decrement had begun to act upon it, as to require for the completion of the Crystal in its modified state, the addition of only those defective plates of molecules by which the modifying planes might be produced. A primary form of this magnitude is evidently the greatest that could be inscribed in the given secondary form; and it is in theory termed the *nucleus* of the secondary form.

(71.) As far as we have proceeded with the theory of Decrements, the diminished plates of molecules have been supposed to be laid constantly upon the *primary* form, in order to produce the modifications which are found to exist in Nature. But it is probable that Decrements sometimes take place on secondary planes. Thus Decrements may be conceived to take place on any secondary rhomboid of carbonate of lime by the abstraction of small masses of primary molecules forming similar minute secondary rhomboids.

Decrements are sometimes related, as will appear in the next section, to the capacity of a body to become electric by heat, but it does not appear that any explanation has been given of the manner in which this influence is exerted.

Of the Law of Symmetry.

(72.) Among the definitions (11.) to (14.) will be found an explanation of *similar edges, angles*, and *planes* of a Crystal.

It has been ascertained from the observation of a great number of the secondary forms of Crystals, that when a modification takes place on any one edge or angle of any primary form, a similar modification generally takes place on all the similar edges or angles. And this has been observed to occur so frequently, as to induce the conclusion of its being the effect of a general law, which Haüy has called the Law of Symmetry. This law, however, does not act universally with regard to all such similar edges or angles as are included under the definitions already given. The tourmaline presents an instance of deviation from it. The primary form of the tourmaline is a rhomboid, and the three upper terminal edges, fig. 8, are *similar* to the three lower ones; the six lateral edges, as well as the six lateral solid angles, are also respectively *similar*. Yet it is found that the three upper terminal edges are sometimes truncated, while those below are not. It is also observed that sometimes only the alternate three of the lateral solid angles are modified, the three others remaining entire; but the tourmaline is pyro-electric, that is, capable of becoming electric by heat: and many other substances which are endued with a similar property, appear equally subject to a similar interference with the general Law of Symmetry.

But other minerals which are not pyro-electric, afford instances of deviation from strictly symmetrical modification; thus iron pyrites present a series of secondary forms which may be termed defective, when compared with those produced from the cube of galena. Pyro-electricity is not, therefore, the only disturbing cause which influences the deviation from the general Law of Symmetry in the formation of Crystals.

Of the Primary Forms of Crystals.

Of the Primary Forms of Crystals.

(73.) It has been stated that the selection of the form which is to be regarded as the primary, is in some degree arbitrary; and we might, as some other writers on Mineralogy have done, have assumed the cube, the regular tetrahedron, the regular octahedron, the rhombic dodecahedron, and the pentagonal dodecahedron, as distinct Primary Forms; under each of which, particular modifications of the cube might have been arranged. Or, we might, in consequence of the general relation which subsists among them, have referred all the modifications of the cube to either of these as the primary.

We might also have assumed either of the octahedrons arising from modification *a* or *c* of the square prisms as the Primary Forms of that system of Crystallization. And the same observation might be applied to the other classes of Primary Forms, it being demonstrable that any one of the forms so related to the others and to the primary, as these modifications are, might be adopted as the fundamental form of the system. But there would be a considerable difference in the facility with which the relations of the secondary forms to the primary could be explained in reference to some of these than to others. Those which are adopted in this

Treatise have been selected on account of the greater facilities they appear to afford for demonstrating those relations.

The Primary Form of every Crystal may be determined either from the primary or the secondary planes; or it may sometimes be deduced from cleavage, or from a consideration of both planes and cleavage. And in the remarks which will follow the tables of modifications, an explanation will be attempted of the manner in which the Primary Form of any crystallized mineral may be discovered.

Of the Secondary Forms of Crystals.

(74.) The Secondary Forms of Crystals differ from the primary in the number or position of their planes, and they are either *simple* or *compound*. The simple Secondary Forms are those which are produced by single modifications. The compound are those in which several modifications occur on one Crystal. The cube with the angles truncated or replaced by three or six planes, is an instance of a simple Secondary Form; but if the edges be also truncated, or bevilled, or the solid angle be both truncated and replaced by three or six planes, it will afford an example of a compound secondary form. These compound Secondary Forms are of very frequent occurrence among minerals.

(75.) The secondary planes frequently obliterate entirely the primary ones, and produce a *new figure*, as in the instance of the rhomboid being converted into a six-sided prism by the truncation of all its solid angles, or of its terminal solid angles and its lateral edges.

(76.) Particular Secondary Forms sometimes predominate in particular species of minerals, as an octahedron in sulphur, whose primary form is a right rhombic prism, and the regular hexagonal pyramid in quartz, whose primary form is a rhomboid.

A dodecahedral variety of carbonate of lime, commonly called dog-tooth spar, occurs the most frequently in Derbyshire.

In Cumberland, the most common variety is a six-sided prism terminated by the planes of an obtuse secondary rhomboid.

In the Hartz, the entire six-sided prism occurs more frequently than in other places. And we have noticed some Crystals from Plymouth which appear to have been originally of the form of the Derbyshire dodecahedrons, and to have been afterwards enlarged by additional particles, which have been so arranged as to convert the dodecahedrons into prisms similar to those from Cumberland. And in some Crystals, the points of the dodecahedrons are seen standing above the summits of the prisms.

Particular Secondary Forms are found to occur constantly among some species of minerals, and rarely among other species belonging to the same class of primary forms.

Thus the regular hexagonal pyramids, which occur constantly among the Secondary Forms of quartz and corundum, rarely occur in carbonate of lime.

The Secondary Forms of some minerals contain only half the number of modifying planes which the law of symmetry requires; as in the instance of the triangular planes on some Crystals of quartz which occur on only one side of the edge of the prism instead of being symmetrically placed on both its sides.

The causes of these peculiar habitudes of minerals are not known; and they appear to belong to that class of facts, which our limited knowledge of the operations of Nature does not enable us at present to comprehend.

Of Hemitrope and Intersected Crystals.

(77.) Besides the secondary forms referred to in the preceding section, there is another class which were termed *macles* by Romé de l'Isle, and by Haüy *hemitrope*, from their resemblance to Crystals which may be supposed to have been cut through, and one-half to have been turned partly round on an imaginary axis, passing through the centre of and perpendicular to the plane of section. The *imaginary axis* being termed the *axis of revolution*, and the *imaginary section* the *plane of revolution*.

This kind of structure may be readily understood from one or two examples.

(78.) If we conceive an octahedron, *a b c d e f*, fig. 50, to be cut through in the direction *g h* parallel to two of its planes; and if we suppose the half, *b d f*, partly turned round, as in fig. 51, until *b* is opposite to *c*, and *d* opposite to *e*, a Hemitrope Crystal would be produced, resembling one of the varieties of the common spinelle.

Again, if we suppose a doubly oblique prism, as in fig. 52, to be cut through in the direction *m n o*.

And if we then conceive one-half to be turned half round, as in fig. 53, we shall have a form of Hemitrope Crystal of frequent occurrence in cleavelandite.

These examples are sufficient to illustrate the manner in which Hemitrope Crystals might be conceived to be produced. The arrangement, however, of the molecules in so apparently capricious a manner, is doubtless the consequence of some law operating on the structure of the Crystal from the commencement of its formation, and analogous to those laws by which other secondary forms are produced.

Crystals of this character may occur among either unmodified primary forms, or secondary forms; the plane of the imaginary section being always parallel either to one of the primary planes, or to some secondary plane which would result from a regular decrement.

Oxide of tin, as shown in Mr. Phillips's Paper on that substance in the IId volume of the *Geological Transactions*, exhibits a considerable variety of forms of this nature. They are very common also in felspar, rutile, and sphene; and they occur in many other substances.

One character by which Hemitrope Crystals may frequently be known, is the re-entering angle which is produced by the meeting of some of their planes. This is very obvious in the figures 51 and 53. But even where this re-entering angle does not appear, there is generally some line, or some other character, which indicates the nature of the Crystal.

The term *twin Crystals* has been applied by some authors to denote these compound forms, upon the supposition that they are pairs of single Crystals united by particular planes.

(79.) Crystals are frequently found intersecting each other with greater regularity than can be ascribed to accident, and forming a class very analogous to Hemitropes, of which the staurotide affords a good example.

The primary form of the staurotide is a right rhombic prism, fig. 54.

Two of these prisms frequently cross each other at right angles, as in fig. 55. And sometimes at an oblique angle.

In other minerals it is sometimes observed, that three, four, or more Crystals intersect each other in this manner, and produce figures apparently remote in character from the primary forms to which they belong. Combined or intersecting Crystals frequently occur in arragonite, in carbonate of lead, in sulphuret of copper, and in other species of minerals.

Of Epigene and Pseudomorphous Crystals.

(80.) The crystalline forms already alluded to are supposed to be the proper forms of the mineral substances among which they occur. But minerals frequently present themselves under other, and what may be termed foreign, forms.

One class of these to which Haüy has applied the name of *Epigene*, consists of Crystals, the substance of which has undergone some chemical change subsequently to their formation.

Thus Crystals of blue carbonate and of red oxide of copper are frequently found converted into green carbonate. Sulphuret and carbonate of iron are changed into oxides, without losing their peculiar crystalline forms; and the same alteration takes place in other minerals.

(81.) Another class of Crystals whose forms are also foreign to the substances in which they occur, have been denominated *Pseudomorphous.* These have been formed either *within cavities* from which Crystals of some other substance have been previously removed by some natural cause, or *upon* Crystals of some other substance, which Crystals have subsequently disappeared; the space they occupied either remaining void, or being found filled with some other matter.

Both these classes of Crystals, particularly the first, may occasion some embarrassment to the young Mineralogist, but this will be lessened by an improved acquaintance with the minerals in which they occur.

The theory of the formation of Pseudomorphous Crystals presents however some difficulties which it does not seem easy to remove. It is not easy to conceive how the Crystals, resembling in their figure those of quartz and carbonate of lime, which are found in what is termed crystallized steatite, could have been formed. The Crystals themselves and the mass in which they are imbedded being apparently composed of homogeneous matter.

Of the Phenomena of Crystallization.

(82.) Little is at present known concerning the nature of those forces or influences which determine mineral bodies to assume crystalline forms, or concerning the causes which produce such a diversity of those forms. Haüy says, that "when the molecules of a body are suspended in a fluid, which afterwards, either by evaporation, or through some other cause, abandons them to their reciprocal affinities, if no disturbing force should interfere, the molecules would unite by those planes the most disposed to such union, and would by their combination produce the regular solids which we term Crystals."

But this explanation of the manner in which a change of state from solution to solidity may take place, does not assist our inquiry into the causes which predispose the molecules to form solids of particular shapes; or why their mutual attractions should cease in particular directions, as in the formation of a cubic Crystal, which is defective at all its solid angles.

Of the Phenomena of Crystallization.

The causes of Crystallization are probably allied to electricity, whose relations are much more extensive than they were formerly supposed. We shall not, however, enter further upon this subject, but shall briefly inquire into the general phenomena of the production of Crystals.

(83.) The different hypotheses which assign an aqueous, or an igneous origin to what has been termed the crust of our earth, suppose the minerals forming that crust to have been produced by analogous causes.

It is however certain that many of the natural Crystals with which we are acquainted, were not formed contemporaneously with the beds in which they have been discovered; but that they have been produced at later periods, and possibly under very different circumstances. Sometimes their origin may be ascribed to the action of heat, sometimes to the solvent power of some fluid, and in other instances to the united influence of both these causes.

The observations of Sir Humphrey Davy "Upon the state of water and aeriform matter in cavities found in certain Crystals," printed in the *Philosophical Transactions* for 1822, render it not improbable that natural Crystals are formed under very different degrees both of pressure and temperature. There are several appearances not uncommon among Crystals, from which it may be inferred that they are sometimes very slowly formed, and that accompanying Crystals of different minerals have been deposited at very different periods.

The Crystals of carbonate of lime which are found at Ecton in Staffordshire, frequently contain numerous minute Crystals of copper pyrites, apparently first deposited on small Crystals of the carbonate of lime. This substance has then formed over the pyrites, and produced a larger Crystal of carbonate of lime, upon which a second deposit of copper pyrites has taken place. This has been again enclosed within a still larger Crystal of the calcareous matter, upon which other Crystals of pyrites have been again deposited. And we may discover, when the Crystals are large, many alternations of these two minerals successively covering each other.

The Crystals which are termed pseudomorphous sometimes afford very distinct evidence of successive formation, as the period at which these were produced must have been posterior to that of the Crystals whose forms they imitate. We have observed in one instance a mould in preparation, if we may so term it, for a pseudomorphous Crystal, from which a part only of the model, a cube of fluate of lime, had been removed, leaving in the cavity only a small loose nodule with an irregular and smooth surface like that of partially dissolved salts.

Hollows of various forms contained within crystallized quartz are not uncommon; but we do not recollect any other instance of the Crystal, whose removal had produced the vacuity, being only in part destroyed, as if its dissolution had been recently going on. Numerous other examples might be cited as evidences of the gradual formation of Crystals, by processes which are probably still in operation, although we are uninformed respecting their nature.

There are circumstances which render it almost certain that some Crystals have been produced from solution in a fluid. The water found in the cavities of certain Crystals of quartz, would seem to refer their origin to

solution in that fluid; and it is known from the copious deposit of silicious matter from the waters of the Geyser in Iceland, and from the hot springs in the Island of St. Michael's, that quartz may be held abundantly in solution by water.

Whether the metals have been deposited from chemical solutions, or from a state of fusion, are points upon which no certain information has been obtained, nor do the few facts which are known throw much general light on the subject.

Some specimens brought from Torre del Greco have been described by Mr. Aikin in the *Geological Transactions*, among which were some minute octahedral Crystals of red oxide of copper attached to the surface of a fused and partly oxidated mass of copper and iron. These must have been produced by sublimation of the particles which composed them.

It appears from a Paper by Dr. Wollaston published in the *Philosophical Transactions* for 1823, that the metallic titanium which he discovered among the slags from some iron-works, is wholly infusible; but he conjectures that it might have been precipitated in its present crystalline forms in the state of oxide, in which it might have been sublimed. And in this manner Crystals of the metals and their ores may possibly have been deposited upon quartz, or upon other earthy substances.

The red oxide of mercury produces sometimes very distinct Crystals by sublimation. And Crystals of calomel and of other substances may be produced in a similar manner.

(84.) The processes of the laboratory are the only means we possess of investigating the phenomena of Crystallization. Some minute Crystals of quartz are said to have been deposited from an alkaline solution of that substance after long standing; and Crystals of carbonate of lime have been observed in vessels which contained the elements of that mineral in solution. Lead may be produced in thin metallic plates from the decomposition of acetate of lead by metallic zinc. Bismuth, antimony, and some other metals may also be made to crystallize by fusion; but these few facts afford no conclusions explanatory of the natural processes of metallic Crystallization. Many experiments have, however, been made with a view to investigate those processes, from which several curious and interesting results have been obtained.

Most bodies have a tendency to crystallize in passing from a state of fusion or solution into a solid state. Water may be said to crystallize at 32° of Fahrenheit, although it does not exhibit regular cleavage planes when broken, and flakes of snow frequently exhibit regular and beautiful forms. Highly concentrated acetous acid becomes solid and assumes a crystalline form at about 50° of Fahrenheit: and mercury crystallizes at about 72° below the freezing point of water, and when in a solid state it is brittle and exhibits a distinct crystalline fracture if broken. Lead, antimony, and most other metals, become fluid at different temperatures above that of boiling water, and when suffered to cool gradually, they may be brought to crystallize with more or less regularity. For this purpose they are to be melted in deep vessels, and when the metal has become solid at the surface by slow cooling, that surface is to be broken, and the metal which remains fluid within, being poured out, the hollow will frequently be found lined with very regular Crystals.

Among the slags from furnaces regular Crystals frequently occur, not only of metallic but of earthy substances.

Of the Phenomena of Crystallization.

(85.) The artificial production of Crystals from solution in a fluid may be considered in reference to the circumstances attending their deposition, to their size, their forms, whether simple or compound, regular or irregular, and to the characters of their planes.

(86.) The variations in the temperature and hygrometric state of the air, but more particularly the latter, will influence the deposition of Crystals. When the air is dry, evaporation proceeds more rapidly, and Crystals are then deposited more freely. Heat, as it promotes evaporation, predisposes a solution to deposit Crystals, which are generally best formed when the evaporation has been slow, and as the solution cools.

But Crystals are not always deposited when even a saturated solution cools.

If a concentrated solution of sulphate of soda be enclosed while hot in a tube, it will not deposit Crystals on cooling; but if air, or gas of any kind, be admitted to it, the whole mass becomes almost instantaneously solid.

(87.) There is a considerable diversity in the manner in which the Crystals of different salts are deposited. Sometimes they stand singly on the bottom of the vessel containing the solution. In other instances their tendency is to form into groups, the Crystals of which appear sometimes to radiate from a common centre. This character is very conspicuous among natural Crystals in wavellite, in some varieties of sulphate of lime, arseniate of cobalt, and other minerals. The Crystals of sulphate of magnesia, of rhombic sulphate of nickel, of nitrate of potash, and many other substances, if rather rapidly produced, form long slender prisms, which so intersect each other as to lie in almost every direction. Carbonate of magnesia does not crystallize, if the quantity dissolved be small, until the bulk of the solution be nearly equal to the bulk of the Crystals that are produced from it. And the solutions of other salts are known to require a high degree of concentration before they will deposit any Crystals.

(88.) The nature of the surface of the vessel containing the solution will influence the precipitation of Crystals. Thus Crystallization is said to take place more rapidly in rough earthenware than in glass vessels, and it is well known that threads, horse-hair, fine wire, sticks of glass, and other foreign bodies introduced into a solution will be covered with Crystals in preference to the surface of the containing vessel.

When a solution is ready to deposit Crystals, they will be immediately produced if a fragment of the substance dissolved be introduced into it. And however irregular the shape of this fragment may be, the irregularities will be found to disappear as it increases in bulk, and a regular Crystal will be produced, which will be enlarged as the evaporation proceeds.

(89.) The size of the Crystals is generally influenced by the volume of the solution and by its depth. When the volume and depth are considerable and the evaporation slow, large Crystals will generally be formed. But in operating upon small quantities of fluid, Crystals of different sizes are frequently produced in the same vessel, and in apparently a capricious manner. And it has been said, that solutions charged with electricity have deposited smaller Crystals than when in their natural state.

Some salts, of which the sulphate of copper and

nickel, and the sulphate of copper and zinc are examples, deposit much larger Crystals during the cooling of a smaller quantity of a saturated hot solution, than from the spontaneous evaporation of a much greater volume at the actual temperature of the atmosphere.

(90.) With regard to the forms of Crystals, those which are considered primary rarely occur among either natural or artificial Crystals, nor has experiment yet pointed out any means by which these may with certainty be produced.

It has been said, that more simple forms are produced when an impalpable powder is mixed with the solution of a salt.

There does not, however, appear to be much constancy in the result of such experiments, but on the contrary different substances appear to possess peculiar habitudes in this respect and not to exhibit corresponding results.

Chemical mixtures influence the forms of Crystals, perhaps more frequently than any other cause, yet in a manner of which we believe at present no clear conception can be formed. Mr. Brochant remarks, with great justice, that the nature of this influence is a highly important point in the History of Crystallization, as it is probable that it very frequently governs the formation of natural Crystals. Some chemical mixtures appear to influence even the primary forms of Crystals, without apparently altering the nature of their chemical constitution, while others merely occasion changes in the modifications of those forms. Thus sulphate of nickel, if crystallized from an acid solution, takes a square prism as the primary form; but if the square prisms thus obtained be dissolved in water and re-crystallized, rhombic prisms are produced, without any apparent atomic difference in the proportions of their respective elements.

The difference between the forms of carbonate of lime and arragonite, which are probably similar chemical compounds, may have resulted from some interference analogous to this; and we may, perhaps, refer to the same cause the difference of figure between the common and the white iron pyrites.

(91.) The faces on which Crystals deposited from solutions rest, are generally extended disproportionately in relation to the other planes. But this is not invariably the case, nor does the position of the deposited Crystal in the solution always influence its figure.

If the crystalline particles were constantly more numerous towards the bottom of the solution than at its surface, it might be supposed that Crystallization would first take place at the bottom, and that the lower planes of immersed Crystals would be the most enlarged; and this is frequently found to be the case.

But several of the salts begin to crystallize almost invariably at the surface; and while the Crystals thus formed sink and increase in size at the bottom, others are successively produced above.

We have remarked also among some Crystals of nitrate of lead, which were deposited together in the same vessel, some which were unmodified octahedrons, and others that were hemitropes. Of the octahedrons, some had their axes perpendicular to the surface on which they rested; others rested on one of their planes; and others were attached by an edge to the bottom of the vessel; a variety of position which excludes the idea of its being the result of any particular law.

The natural planes of Crystals are subject to a considerable diversity of character, some possessing the highest degree of brilliancy, and others being so dull as to afford no distinct reflections. Sometimes they are striated, sometimes curved, and they commonly exhibit greater or less degrees of inequality. Particular planes of some Crystals are frequently marked by some distinguishing peculiarity which occurs also on the corresponding planes of other Crystals, of the same substance. Thus the planes which truncate the primary terminal edges of the Crystals of carbonate of lime are generally striated parallel to their edges of combination; and the terminal planes of hexagonal prisms of that substance are generally opaque and dull.

Among artificial Crystals a difference is frequently observable in the characters of the planes, but it is not constant even under analogous circumstances. Sometimes the most perfect planes appear on those Crystals which have been slowly formed, and sometimes on those which have been rapidly produced, particularly in some of the double salts. We have repeatedly tried to obtain by slow evaporation Crystals of the sulphate of copper and zinc with bright planes, but without success; yet they have been immediately produced on the cooling of a hot saturated solution, and we have observed more perfect Crystals of sulphate of copper produced in this manner than from slow evaporation.

It must, however, be admitted that these experiments and facts do not afford the desired illustration of the natural processes of Crystallization.

Of the Tables of Modifications.

(92.) Crystals of different minerals may belong to the same system of Crystallization. Thus fluate of lime and sulphuret of silver are both referable to the cube. Carbonate of lime and red silver are both rhomboids. Sulphate of lead and hydrous oxide of iron are both right rhombic prisms. And so of other minerals.

When several species are related to one system, or, as we shall henceforth express ourselves, to one class of primary forms, they will, unless that class be the cube, generally be found to differ from each other, in the mutual inclination of their primary planes, or in the comparative lengths of some of their primary edges.

(93.) Crystals rarely present themselves under their respective primary forms, but are usually modified by new planes, producing secondary Crystals, from which the primary are to be inferred. Hence an accurate knowledge of the relations between the secondary and primary forms of Crystals is essential to a correct crystallographical discrimination of minerals.

The secondary forms of Crystals have been explained to consist of Modifications of the primary, occasioned by decrements on some of their edges or angles, the laws of which will be afterwards investigated. But as there are many who form collections of minerals as an amusement, and others who pursue some branch of Mineralogy as a business, and who from want of inclination, or leisure, or a habit of engaging in such inquiries, are disinclined to undertake a geometrical investigation of the relations of Crystals, we have attempted to supply another method of exhibiting those relations in the following Tables of Modifications of the primary forms, and the explanations which follow them. And although these may not furnish the Mineralogist with all the assistance he requires, his study of Crystals will be

materially assisted by the opportunity they will afford him of comparing all the primary and simple secondary forms with each other, and of obtaining a general view of the entire series of simple secondary forms under which Crystals may present themselves. And as the most compound secondary forms are only combinations of two or more simple Modifications, these Tables will explain the most complicated figures of Crystals.

(94.) The Tables contain not only the *observed* Modifications of Crystals, but the entire series of which each class of the primary forms is susceptible while influenced by the law of symmetry, with the addition of some of the observed instances of departure from this law in the production of what may be termed incomplete secondary forms.

From a general view of the Tables, it will be seen that the first Modifications are those on the angles of the primary form; these being succeeded by the Modifications on the edges; beginning in all cases with the simplest change of form.

It has been already stated, that each class of the primary forms may comprise many series of Crystals belonging to as many different species of minerals. And in the same manner each of the Modifications, excepting those which produce tangent planes, may include a number of individual or particular planes differing from each other in the angles at which they respectively incline on the adjacent primary planes.

Thus a series of modifying planes comprehended under *b* in the Modifications of the cube may occur within two natural limits; the one the primary plane of the cube, and the other the plane *a*. For it is obvious that the inclination of *b* on P may approach nearly to 180°, but it can never reach that limit. And it may pass from this position through perhaps an unlimited series inclining less and less on P, until at length the inclination would be nearly the same as that of *a* on P; but it is apparent that it can never attain this limit, there being no other plane than *a* which can incline to the primary planes at the same angle that *a* does.

The series of planes belonging to Modification *c* of the cube, are limited within the planes *a* and *c*. The angle at which the planes marked c incline to each other, may be conceived to increase, until it approaches very nearly to 180°; the three planes would then very nearly become one, or be nearly similar to *a*, but they can never reach that limit. And they may also be conceived to incline more and more upon the edge, until at length they would very nearly coincide with the planes *e*, but they could never exactly coincide with those planes.

The series of particular Modifications of the cube comprehended under *d*, may be conceived to lie within several limits, according to the direction in which the change of position of the modifying planes may be supposed to take place. The angle at which the two planes *d*, which rest on P′, incline to each other may be imagined to increase until they nearly approach to one plane, corresponding with *b*, or the angle at which the two planes *d*, which meet at the edge of the cube, incline to each other, may approach nearly to 180°, when they would nearly become analogous to *c*. Or if the two planes *d*, which meet at the edge of the cube, be conceived to incline more and more on that edge, they will at length approach nearly to the position of the planes *f*, but they can never coincide with those planes.

These remarks on the nature of the differences among the planes belonging to some of the Modifications, might easily be extended to all. But it will not be difficult for the reader to apply them himself to all the other variable ones. The nature of the variation, however, will occasionally be pointed out in the Tables.

(95.) When the new planes which would result from any particular Modification are so much extended as to efface the primary planes, a new solid will evidently result. The series of new solids which might result from any single Modification, will be found generally to possess one common character: that is, their planes will generally be all triangular, or all quadrilateral, or all pentagonal, or some other common figure; but this is not invariably so. Among the series of secondary forms resulting from particular Modifications of the rhomboid, some will be contained within scalene triangular planes, and others belonging to the same Modification within isosceles triangular planes, as will be pointed out in the Tables.

(96.) A particular position is chosen in these Tables for the figure of each of the primary forms, and the same is retained in the series of Modifications.

The right rhombic prism is supposed to have its greater diagonal horizontal.

In the oblique rhombic and doubly oblique prisms the angles of P with M and T are supposed to be obtuse; and if the figures of Crystals of different substances belonging to the same class of primary forms, were always placed in the same positions as those in the Tables, they might more easily be compared with each other, and their peculiar characters be more readily described.

(97.) On each of the primary forms certain letters are placed, which are intended to designate the angles, edges, and planes of Crystals, and to denote their similarity or dissimilarity.

Some or all of the vowels A E I O are used to designate the *plane angles* of the primary form; some of the consonants, B C D F G H, to designate the *primary edges*, and P M T the *primary planes* of Crystals.

The same letter is repeated where the angles, edges, or planes are similar; and different letters are used where those angles, edges, or planes are dissimilar, according to the definitions of similar angles, &c., already given (11.) to (14.)

Thus the letter A is repeated on the four angles of the cube, these being all similar; while A and E are placed on the alternate angles of the right rhombic prism to show that in that figure those angles only are similar which are opposite to each other.

In the cube the letter P is repeated on all the planes, because they are all similar.

In the right rhombic prism the letter P stands on the terminal plane, and M on the lateral planes, implying that these are not similar to the terminal plane; but M being repeated on both the lateral planes, denotes that these are similar to each other. When M stands on one and T on the other, they are dissimilar.

The ′ and ″, (which are to be read dash and two dash,) added to some of these letters, serve merely to distinguish two or more similar edges, angles, or planes from each other.

By carefully observing the letters thus used to designate the planes, &c., the class of primary forms to which any figure, drawn according to this method, belongs, may be readily discovered.

When the planes of a Crystal are parallel, if taken

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in pairs, not more than one half of their number can be rendered visible in the front of the drawing; but when the planes are not all parallel, as in the tetrahedron, more than half may be exhibited according to the position of the Crystal. For it is evident that if the tetrahedron be held with a solid angle nearest to the eye, three of its four planes will be seen at the same time.

It may be remarked that the modifying planes contained in the Tables, are produced by cutting off portions of the figure of the primary Crystal, and thus reducing its bulk. It is almost unnecessary, after what has been already said on the formation of Crystals, to observe, that nature proceeds by building up the secondary forms instead of thus truncating the primary. And we may, if we please, imagine that the secondary figures given in these Tables, have been produced by additions to primary Crystals of smaller relative dimensions.

The inclination of any two planes to each other, as P, and Modification a of the cube, or the angle at which they meet, may be expressed by P on a, or a on P, or simply by P,a, or a,P, adding the value of the angle in degrees and minutes.

Tables of the Primary Forms and their Modifications.

THE CUBE.

Fig. 56.

(99.) *Mod. a*, fig. 57. The solid angles replaced by tangent planes, whose surfaces are equilateral triangles.

When the modifying planes are extended so as to efface the primary planes, a regular octahedron is produced.

$$P,a = 125^\circ\ 15'\ 52''$$
$$a,a' = 109^\circ\ 28'\ 16''$$
$$a',a'' = 70^\circ\ 31'\ 44''$$

Mod. b, fig. 58. The solid angles replaced by three planes resting on the primary planes.

From this Modification a series of new figures might result, each of which would be contained within twenty-four equal trapezoidal planes; the trapezoids being dissimilar in the different members of the series, and inclining at different angles on the primary planes and on each other. The different members of every other series of new figures which can result from any Modification of this or any other Primary Form will *generally* agree in the character of their planes, but these will always differ in their inclination to the primary and to each other. An observation which it will not be necessary to repeat in reference to any series belonging to any other of the Primary Forms.

Mod. c, fig. 59. The solid angles replaced by three planes resting on the primary edges.

New figures contained within twenty-four equal isosceles triangular planes.

Mod. d, fig. 60. The solid angles replaced by six planes.

New figures contained within forty-eight triangular planes.

Mod. e, fig. 61. The edges replaced by tangent planes.

New figure the rhombic dodecahedron.

$$P,e = 135^\circ$$
$$e,e' = 120^\circ$$

Mod. f, fig. 62. The edges replaced by two planes.

New figures contained within twenty-four triangular planes.

Tables of the Primary Forms and their Modifications.

(100.) Some of the forms assumed to be derived from the cube, contain only half the number of modifying planes which the law of symmetry requires. Of these there are two different sets. One belonging to the tetrahedron, the other to a pentagonal dodecahedron; and as these are the predominating figures of some species of minerals, it will be convenient to denote their relations to the cube in the following manner.

In fig. 63 the planes a appear only on the *alternate* solid angles, and present only half the number of planes required by the law of symmetry. The figure may therefore be denoted by *Mod.* $\frac{a}{2}$. When these planes are so much extended as to efface the primary planes, a regular tetrahedron would be produced, as shown by the lines on the figure. And it is evident that this same form would be produced, but in a transverse position, if the modifying planes were placed on those angles which are entire on the figure.

The planes b, c, and d occur also on the *alternate* solid angles, and may be denoted by $\frac{b}{2}$, $\frac{c}{2}$, and $\frac{d}{2}$. It is evident that the planes of this class of hemi-forms, as they may be termed, are not parallel, but inclined to each other; a character by which they may be distinguished from the following.

(101.) When the cube is modified by only twelve of the planes of *Mod. f*, as shown in fig. 64, a series of pentagonal dodecahedrons will be produced, contained within six pairs of *parallel* planes. The relation of this figure to figure 62, is seen by the corresponding letters on the planes of each. This class may, on account of the *parallelism* of its planes, be denoted by $\frac{f}{2}\,\|$, and as three only of the six planes of *Mod. d* sometimes occur on each solid angle, these may be denoted by $\frac{d}{2}\,\|$. The addition of $\|$, the symbol of parallelism, being sufficient to distinguish these from the planes already denoted by $\frac{a}{2}$, $\frac{b}{2}$, $\frac{c}{2}$, and $\frac{d}{2}$.

THE SQUARE PRISM.

Fig. 65.

(102.) The Crystals of different minerals belonging to this class may differ from each other in the comparative lengths of the edges B and G.

Mod. a, fig. 66. The solid angles replaced by single planes which are isosceles triangles.

This Modification would produce a series of four sided pyramids, resting on the lateral edges of the prism. And when the modifying planes are so much enlarged as to efface the primary, a series of octahedrons with square bases will result.

The planes a incline equally on M and M′, but at a different angle from that at which they incline on P. A character by which this form is distinguished from the cube, where a inclines equally on the adjacent primary planes.

Mod. b, fig. 67. The solid angles replaced by two planes.

The new figures are bi-pyramidal, and contained within sixteen sides.

(103.) The two planes of this Modification may intersect the planes M, M′, parallel to a diagonal or other-

wise, according to the nature of the decrement by which they are produced.

When both planes occur on a Crystal, and intersect M and M′ parallel to a diagonal, it will be convenient to denote them by the character $b_{\prime\prime}$ and the series of such planes may be distinguished by $b_{\prime}1$, $b_{\prime}2$, $b_{\prime}3$, &c. When they result from intermediary decrements, and consequently do not intersect M or M′ parallel to a diagonal, they may be denoted simply by *b*.

If only one of the two planes *b* should appear on the Crystal, it may be denoted by $\frac{_{\prime}b}{2}$ or $\frac{b_{\prime}}{2}$, if parallel to a diagonal on the left or right of the figure, and by $l\frac{b}{2}$ or $\frac{b}{2}r$, if not parallel to a diagonal.

The same observations will apply to the planes *b* and *d* of the right and oblique rhombic prisms.

Mod. c, fig. 68. The terminal edges replaced by single planes not forming equal angles with the terminal and lateral planes, producing a series of four-sided pyramids resting on the lateral planes of the prism, and, by an extension of the modifying planes, a series of octahedrons with square bases.

Mod. d, fig. 69. The edges of the prism replaced by tangent planes.

Mod. e, fig. 70. The edges of the prism replaced by two planes.

The separate Modifications of the terminal edges, or the lateral edges, will distinguish the secondary Crystals of this class of prisms from those of the cube.

THE RIGHT RHOMBIC PRISM.

Fig. 71.

(104.) The solid angles at A are the *obtuse*, and those at E the *acute* solid angles. The edge G is the *acute*, and H the *obtuse* lateral edge of the prism.

The particular prisms belonging to different minerals may differ from each other in the inclination of M on M′, or in the ratio of the edge B to the edge H.

Mod. a, fig. 72. The obtuse solid angles replaced by single planes which intersect the terminal plane parallel to its greater diagonal.

When the planes *a* increase, the secondary form may be an octahedron with a rectangular base, as shown in fig. 73.

Mod. b, fig. 74. The obtuse solid angles replaced by two planes.

This Modification would produce a series of four-sided pyramids, and the new figures would be octahedrons with rhombic bases.

Mod. c, fig. 75. The acute solid angles replaced by single planes, which intersect the terminal plane parallel to its short diagonal.

An octahedron with a rectangular base, as shown in fig. 76, might result from this Modification.

Mod. d, fig. 77. The acute solid angles replaced by two planes.

The new figures would be octahedrons with rhombic bases.

The planes *b* and *d* may be denoted as in the square prism.

Mod. e, fig. 78. The terminal edges replaced by single planes.

This Modification would produce a series of four-sided pyramids, and the new figures would be octahedrons with rhombic bases.

Tables of the Primary Forms and their Modifications.

Mod. f, fig. 79. The obtuse lateral edges replaced by tangent planes.

Mod. g, fig. 80. The obtuse lateral edges replaced by two planes.

When the primary lateral planes are effaced by the planes *g*, a series of secondary Right Rhombic Prisms would be produced.

Mod. h, fig. 81. The acute lateral edges replaced by tangent planes.

Mod. i, fig. 82. The acute lateral edges replaced by two planes.

This Modification would produce another series of secondary prisms.

THE OBLIQUE RHOMBIC PRISM.

Fig. 83.

(105.) The figure is supposed to be oblique in the direction O A, so that the terminal plane forms an obtuse angle with the edge H. The planes M M′ may meet at an acute, or an obtuse angle. The solid angle at A is in either case termed the *acute*, and that at O the *obtuse*, and those at E the lateral solid angles.

The edges B are the *acute*, and those at D the *obtuse* terminal edges. The edge H and its opposite are the *oblique*, and G and G′ the *lateral* edges of the prism.

The Crystals of this form belonging to different minerals may differ from each other in the inclination of P on M, or of M on M′, or in the ratio of an edge D to an edge H.

Mod. a, fig. 84. The obtuse solid angles replaced by single planes.

Mod. b, fig. 85. The obtuse solid angles replaced by two planes.

Mod. c, fig. 86. The acute solid angles replaced by single planes.

Mod. d, fig. 87. The acute solid angles replaced by two planes.

The planes *b* and *d* may be denoted as in the square prism.

Mod. e, fig. 88. The lateral solid angles replaced by single planes.

(106.) The planes of this Modification may cut the terminal or lateral planes parallel to a diagonal, or otherwise according to the decrement by which they are produced. If *e* cuts the terminal plane parallel to a diagonal, it may be denoted by $\bar{e}$; if the plane ∥ M′ by $_{\prime}e$; and if the plane M, by $e_{\prime}$. And a corresponding notation may be applied to the planes *a*, *b*, *c*, and *d*, of the doubly oblique prism.

Mod. f, fig. 89. The obtuse terminal edges replaced by single planes.

Mod. g, fig. 90. The acute terminal edges replaced by single planes.

Mod. h, fig. 91. The oblique edges of the prism replaced by tangent planes.

Mod. i, fig. 92. The oblique edges of the prism replaced by two planes.

Mod. k, fig. 93. The lateral edges of the prism replaced by tangent planes.

Mod. l, fig. 94. The lateral edges of the prism replaced by two planes.

Mod. i and *l* would produce other Oblique Rhombic Prisms, varying from the primary and from each other, in the angles at which their lateral planes would meet.

This class of prisms may generally be distinguished from rhomboids by the unequal inclination of the plane *c* to three adjacent primary planes, and by the dissimilarity of the planes *f* and *h*, or *g* and *k*.

THE DOUBLY OBLIQUE PRISM.

Fig. 95.

(107.) In this class of prisms the inclinations of P on M, P on T, and M on T, are all different.

The edges and angles of these prisms may be designated by the same terms as have been used for the corresponding ones of the oblique rhombic prism.

The different Crystals belonging to this class may differ from each other in the inclination of P on M, P on T, and M on T, and in the ratios of the edges D, F, and H.

Mod. a, fig. 96. The obtuse solid angles replaced by single planes.

Mod. b, fig. 97. The acute solid angles replaced by single planes.

Mod. c, fig. 98. The lateral solid angles E replaced by single planes.

Mod. d, fig. 99. Lateral solid angles I replaced by single planes.

Planes *a*, *b*, *c*, and *d* may be denoted similarly to those of *Mod. e* of the oblique rhombic prism.

Mod. e, fig. 100. The obtuse terminal edges D replaced by single planes.

Mod. f, fig. 101. The acute terminal edges C replaced by single planes.

Mod. g, fig. 102. The acute terminal edges D replaced by single planes.

Mod. h, fig. 103. The obtuse terminal edges F replaced by single planes.

Mod. i, fig. 104. The oblique edges of the prism replaced by single planes.

Mod. k, fig. 105. The lateral edges of the prism replaced by single planes.

From the dissimilarity of any two adjacent edges or angles of this class, the separate Modifications produce only single planes; but several varieties of these may occur on the same edge or angle. The secondary forms belonging to this class, are among the most difficult Crystals to be understood.

THE RHOMBOID.

Fig. 106.

(108.) The angle at T is the *superior*, that at O the *inferior*, and those at E the *lateral* angles of the plane P. The edges B are the *superior*, and those at D the *inferior* edges of the same plane.

The solid angle at A is the *terminal*, and those at E and O are the *lateral* solid angles. The edges B are the *terminal*, and D the *lateral* edges of the Rhomboid.

Rhomboids are distinguished from each other by the inclination of P on P′. When P on P′ measures more than 90°, the Rhomboid is called obtuse; when less it is called acute.

Mod. a, fig. 107. The terminal solid angles replaced by tangent planes.

Mod. b, fig. 108. The terminal solid angles replaced by three planes resting on the primary planes.

Mod. c, fig. 109. The terminal solid angles replaced by three planes resting on the primary edges.

Each of the Modifications *b* and *c* would produce a series of Rhomboids more obtuse than the primary; but differing in their relative positions.

Tables of the Primary Forms and their Modifications.

Mod. d, fig. 110. The terminal solid angles replaced by six planes. The new figures are obtuse dodecahedrons whose planes are generally scalene triangles.

Mod. e, fig. 111. The lateral solid angles replaced by single planes *parallel to the axis* of the Rhomboid.

These planes are the lateral planes of a regular hexagonal prism.

Mod. f, fig. 112. The lateral solid angles replaced by two planes, whose edge of intersection is parallel to the axis of the Rhomboid.

These planes represent the lateral planes of a series of dodecahedral prisms.

Mod. g, fig. 113. The lateral solid angles replaced by single planes intersecting the primary planes *parallel to their oblique diagonals.*

The new figure would be a Rhomboid more acute than the primary.

Mod. h, fig. 114. The lateral solid angles replaced by two planes intersecting the primary planes *parallel to their oblique diagonals.*

The new figures would be acute dodecahedrons, whose planes are generally scalene triangles.

Mod. i, fig. 115. The lateral solid angles replaced by single planes which *intersect the primary planes in lines that converge towards the summits.*

The new figures would be Rhomboids, more acute than the primary.

Mod. k, fig. 116. The lateral solid angles replaced by two planes, which intersect the primary planes similar to *Mod. i.*

The new figures are generally acute dodecahedrons with scalene triangular planes.

Mod. l, fig. 117. The lateral solid angles replaced by single planes, *whose intersection with the primary planes converge toward the inferior angles.*

This Modification produces Rhomboids more acute than the primary, but in an inverse position to those of *Mod. i.*

Mod. m, fig. 118. The lateral solid angles replaced by two planes, whose intersections with the primary planes are similar to those of *Mod. l.*

The new figures are acute dodecahedrons, generally with scalene triangular planes, and in an inverse position to those of *Mod. h* or *k*.

Mod. n, fig. 119. The terminal edges replaced by tangent planes producing a Rhomboid more obtuse than the primary.

Mod. o, fig. 120. The terminal edges replaced by two planes.

The new figures are obtuse dodecahedrons, whose planes are generally isosceles triangles.

Mod. p, fig. 121. The lateral edges replaced by tangent planes.

Planes *p* are the lateral planes of a regular hexagonal prism.

Mod. q, fig. 122. The lateral edges replaced by two planes.

From this Modification there results a series of dodecahedrons, whose planes are always scalene triangles.

Some of the Modifications of the Rhomboid and the secondary forms which they produce, bear a general resemblance to those of the oblique rhombic prism, as will be readily perceived by comparing *Mod. a* of the prism with *a* of the Rhomboid. And by respectively comparing *g* and *f* of the prism with *n* and *p* of the Rhomboid.

But these forms may be distinguished by the equal inclination of *a* of the Rhomboid on the three adjacent planes; or by the simultaneous Modification of the three terminal or six lateral edges of the Rhomboid.

When the primary planes of the Rhomboid are effaced by secondary planes, it is only by observing the direction of the cleavage planes, or some other determinate character, that the Modification to which the secondary figure belongs can be ascertained.

Of the Application of the preceding Tables.

(109.) The preceding Tables and remarks will have afforded the reader such a general outline of the relations among the several primary and secondary forms of Crystals, as will enable him in very many cases to determine at once the primary form and modification of any given Crystal. But he may not be enabled to do this generally without some further explanation of the method of what may be termed *reading* Crystals.

The practical use of Crystallography is, as we have before stated, to enable the Mineralogist to determine the species of a mineral from an examination of its crystalline forms.

These forms are either primary or secondary; they are frequently very complicated; and the Crystals from which they are to be determined, are generally only fragments detached from the matrix on which they have been produced, and are occasionally very imperfect.

(110.) The regular symmetry of the secondary forms of the *cube* is such as to admit little doubt concerning the primary in those cases where the secondary planes can be distinctly recognised. But the planes *a* of the regular octahedron are not always distinguishable from those of *Mod. a* of the square prism, without measurement.

(111.) The secondary forms of the *square prism* may generally be distinguished from those of the cube by the want of simultaneous and similar Modifications on the lateral *and* terminal edges, and by the difference of measurement between the octahedrons derived from it and the regular octahedron.

(112.) When there is only a single set of cleavages parallel to the lateral planes of a square prism, the planes parallel to the cleavage are assumed to be the primary. If there are two sets of cleavages, parallel to the planes M and *d*, either of these might be considered the primary set; and in respect of any Crystals already described we can only ascertain which set has been assumed as the primary by a comparison of the Crystals themselves with the published descriptions and figures.

(113.) The *right rhombic prism* presents very little analogy to either of the preceding forms, unless the inclination of the lateral planes upon each other is very nearly a right angle. The octahedrons which might then result from *Mod. e* would nearly resemble those of the square prism, as the inclination of e on e' would be nearly the same as that of e' on e''. But the rhombic prism may then be distinguished from the square prism by either of the *Mods. f* or *g* or *h* or *i* appearing singly on the Crystal.

There is sometimes a cleavage corresponding to the position of the planes M, M′, in Crystals belonging to this form, in which case those planes are determined from the cleavage. But occasionally the only apparent cleavages are parallel to *f* or *h*, in which case the planes, which are to be regarded as M M′, must be inferred from some analogy to other Crystals.

Of the Application of the preceding Tables.

(114.) The *oblique rhombic prism* will be distinguishable from the right rhombic even when the inclination of P on M is very nearly 90°, by the want of correspondig planes on the front and back of the Crystal in the Modifications *a* or *c*, *b*, or *d*, and *f* or *g*, as may be seen by comparing those respectively with Modifications *a*, *b*, and *c* of the right rhombic prism.

The distinction between the secondary forms of this prism and of the rhomboid have been already pointed out in the Tables of Modifications.

The primary planes of this class of prisms are to be determined either by cleavage or from its secondary planes. The varieties of cleavage that occasionally present themselves may be seen by referring to the different minerals whose Crystals assume this form.

(115.) The *doubly oblique prism* will be found the most difficult of all the primary forms to determine from its secondary Crystals. It is distinguishable from all other forms when its Crystals are single, by the absence of symmetrical planes analogous to those of other prisms; but it very frequently occurs in hemitrope or twin Crystals, which must resemble some of the forms of the oblique rhombic prism, and can then be distinguished only by some reentering angle or other character on the surface of the Crystal. The best guide to a knowledge of these forms is an attentive examination of the Crystals of axinite for simple figures, and cleavelandite for hemitrope forms.

(116.) The *rhomboid* will generally be readily distinguished from all other forms by its three or six-sided pyramidal terminations, and by the three, or six, or nine, or twelve-sided prisms which are derived from it. An examination of the Crystals of carbonate of lime and of oligiste iron will afford abundant examples of secondary forms belonging to this figure.

It will be seen by the Tables of Modifications of the rhomboid, that any mineral may present numerous secondary rhomboids as well as the primary, either of which might be assumed as the fundamental form of the whole. But it is usual to regard that particular rhomboid as the primary, which is indicated by the cleavage planes.

(117.) The manner of holding a Crystal for examination requires some attention on the part of the observer, whose first object should be to discover two or more symmetrical planes, and to hold these either vertically or horizontally as they appear to be either lateral or terminal planes corresponding with some of the figures in the tables. The Crystal may then be attached to a piece of wax-taper in a position corresponding to the apparent symmetry of its planes, and be more minutely examined.

(118.) A circumstance which has not yet been alluded to, but which is by no means of uncommon occurrence, a very disproportionate extension of particular planes, will frequently increase the difficulty of *reading* a Crystal. A very remarkable instance of this character prevails in copper pyrites, and has been the occasion of the erroneous opinions entertained until lately, respecting the primary form of that substance.

In all the works on Mineralogy, prior to that of Professor Mohs, its primary form is stated to be a regular tetrahedron. Mohs, however, discovered that the Crystal was an octahedron with a square base. The two following figures represent Crystals containing *equal numbers of similar planes*; fig. 123 having these planes regularly placed on the octahedron, and fig. 124 repre-

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senting the Crystal as it frequently occurs in nature, with some of its planes considerably enlarged. The same letters are placed on the corresponding planes of each, which are in parallel positions on both figures.

When Crystals of this irregular character occur, it is only by cleavage and by using the goniometer that their true forms can be accurately determined.

Having ascertained by examination and comparison with the tables the *class* of primary forms to which any given Crystal belongs, the angles of its primary and secondary planes must be measured in order to determine the species of the mineral.

(119.) When a Crystal, whose primary and secondary forms are known, is to be described by the assistance of the preceding tables, the primary form is first to be set down, and its Modifications denoted by the letters under which they are arranged in the Tables.

But as each Modification, except those which consist of tangent planes, comprehends an unlimited number of separate planes, differing from each other in the angles at which they incline on the primary, it becomes necessary to add to the tabular letter which expresses the Modification, the angles at which the observed planes incline on the adjacent primary ones.

It has been already seen that *Mod. b* of the square prism, represents an indefinite number of planes varying in their respective inclinations on P, M, and M′. Let a given square prism be modified by planes corresponding to b, and let the inclination of one of the planes on P, M, and M′ be denoted by x, y, and z, these letters signifying any number of degrees and minutes.

A Crystal containing the primary planes of the square prism, and a set of planes belonging to b might then be thus described:

$$\text{Square prism } b\begin{cases} b,\mathrm{P} = x \\ b,\mathrm{M} = y \\ b,\mathrm{M}' = z. \end{cases}$$

The character of the plane being thus established, it may afterwards, in order to avoid the repetition of the measurements, be described as $b1$.

Let us now suppose on another Crystal, another set of planes of the same Modification, inclining on P, M, and M′, at the angles x', y', and z', and a third set inclining on P, M, and M′, at the angles x'', y'', and z''; these planes may be described as $b2$ and $b3$:

$$b2\begin{cases} b2,\mathrm{P} = x' \\ b2,\mathrm{M} = y' \\ b2,\mathrm{M}' = z' \end{cases}$$

$$b3\begin{cases} b3,\mathrm{P} = x'' \\ b3,\mathrm{M} = y'' \\ b3,\mathrm{M}' = z''. \end{cases}$$

It will be convenient to call that plane No. 1, which inclines at the most obtuse angle on the primary plane to which it is referred; that No. 2, which is next in its inclination; and so to denote the series in the order of their respective inclinations on the same primary plane.

This method of description may be applied, whether the three planes have occurred on the same or on different Crystals.

The inclination of the modifying plane on two of the primary planes, is generally sufficient, when a solid angle is modified, for determining the law of decrement; but the third inclination serves as a check upon the accuracy of the other two.

If the lateral edge of any prism whose angles are known, be modified by one or more planes, it will be sufficient to give the inclination of each on either of the lateral primary planes, from which the inclination on the other may be readily deduced.

Of the Symbols employed.

This method of description may be extended to all classes of primary forms; and will convey an accurate description of the planes to which it refers.

Crystals may frequently present themselves whose primary forms are unknown to the observer, and whose secondary planes do not enable him to determine them; in which case drawings of the Crystals should be given, accompanied by the measured angles of the several planes. And it may be remarked that the most valuable information a Mineralogist can receive relative to Crystals, is accurate measurements of their angles, accompanied by figures of the measured Crystals.

The laws of decrement are required for drawing these figures with accuracy; but the figures drawn by the late Mr. Phillips merely from the Crystals themselves, prove that a sufficiently precise idea of the forms of Crystals may be conveyed independently of the laws of decrement, to identify any crystallized mineral from the given figures and measurements.

(120.) It has been seen, that the Modifications on the angles of some of the primary forms comprise planes which are produced by different kinds of decrement, some of which are distinguished by the character —, or \, or /, added to the letter denoting the Modification. And it may possibly appear to some of our readers, that different Modifications ought to have been established for these different planes. This would, however, have rendered the Tables less generally applicable to the description of secondary forms, independently of the theory of decrements, than they are at present, which will be obvious on referring to *Mod. a, b, c,* or *d*, of the doubly oblique prism. All that can be known of any individual plane belonging to either of these, independently of calculation, is, that it belongs to such a Modification, and inclines on two of the adjacent primary planes at particular angles; and this furnishes an accurate record of the particular plane.

But if *Mod. a* had been divided into four classes, it could not be known, without previous calculation, to which of those an observed plane ought to be referred; and the measurement of the Crystal would not in such case afford a sufficient description of the secondary form.

It will be convenient while measuring Crystals to recollect that the sum of the angles at which any plane, whose edges are parallel, inclines on the two planes it intersects, is always equal to the mutual inclination of those planes, increased by 180°. Thus if M on T of the doubly oblique prism measure 117°, and M on i measure 110°, i on T will measure 117° + 180° — 110°.

PART II.

Of the Symbols employed to represent the Laws of Decrement by which the Secondary Planes of Crystals may be produced.

(121.) It has been shown that the molecules in the edges of the *defect* of any primary form occasioned by any law of decrement, are respectively proportional to the numbers by which such law may be expressed. These numbers may be denoted by the letters p, q, r; p and q referring to the terminal edges, and r to the lateral edges.

When a terminal edge is modified, the ratio of p to r will express the law of the modifying plane. When a lateral edge is replaced by a plane, its law will be ex-

pressed by $\frac{p}{q}$. When a plane resulting from a simple decrement replaces an angle, and *intersects the terminal plane parallel to a diagonal,* it will be denoted by $\frac{p}{r}$; q being in this case equal to p, and therefore unnecessary to be introduced into the expression of the law; if the modifying plane intersects a *lateral* plane parallel to a diagonal, q and r must be equal, and the law may be denoted by $\frac{p}{q}$, which will also distinguish this from the preceding class of planes.

(122.) In the Tables of Modifications certain letters are placed on the figures of the primary forms, to denote their edges, angles, and planes.

The order of these letters, A E I O, B C D F, G H, is that of the alphabet, arranged from left to right, according to the ordinary method of writing.

The planes which are parallel to those exhibited in the several primary forms, may be denoted by prefixing the symbol of parallelism ‖ to the letters on those planes, as ‖ P, ‖ M, ‖ T.

(123.) In describing a secondary Crystal, whose primary form is known, and upon whose similar edges or angles any number of new planes have been produced, it is sufficient, generally, to express the law of a single plane of each set. For the change of figure which any primary form has undergone would thus be indicated. And in drawing the Crystal corresponding planes would be placed upon all its similar edges or angles.

It sometimes, however, occurs that all the similar edges or angles of Crystals are not similarly modified, and it will therefore be necessary in these cases to indicate the absence of the modifying plane from some edge or angle, where, according to the law of symmetry, it ought to appear.

Distinct kinds of symbols are also required to distinguish simple from intermediary decrements.

The following examples of the forms and application of symbols to denote the Modifications of a doubly oblique prism will include both these classes, and will sufficiently explain the method of using them.

(124.) The Crystal to be described is first supposed to be held *with the plane marked* P, *horizontal, and with that edge or angle nearest to the eye, on which the decrement to be described has taken place.*

Let the Crystal be modified by a plane belonging to the series comprehended under *Mod. a.*

These planes may incline more or less on either of the adjacent primary planes, and may result either from simple or intermediary decrements.

If the modifying plane intersects the terminal plane parallel to its diagonal, and is occasioned by a decrement of one row of molecules, its symbol is $\overset{1}{O}$, and may be read, one over O. If the decrement consist of two rows in breadth, the symbol is $\overset{2}{O}$, and if by three rows in breadth and two in height, it is $\overset{\frac{3}{2}}{O}$; and so of any other decrement in that direction.

If any plane *a* intersects the plane M parallel to its diagonal, and is produced by a decrement by v rows of molecules, v representing *any whole number or fraction,* it is to be denoted by ${}_{v}O$, and be read, v on the left of O.

If it intersects the plane T parallel to its diagonal, it is to be denoted by O_{v}, and be read, v on the right of O.

If the plane has been produced by an intermediary decrement, consisting of two molecules in the direction of the edge H, three in the direction of D, and four in the direction of F, its symbol is (D 3, H 2, F 4,) and may be read, 3 on the edge D, 2 on H, 4 on F. Of the Symbols employed.

If similar Modifications take place at the angle A, *that angle* is imagined to be *nearest to the eye,* and the new planes are to be described in the same manner as those at the angle O.

If two or more planes modify the same solid angle, the symbols representing them are to be placed immediately following each other. Thus, if the three planes at the angle O should occur on the same Crystal, its change of figure would be thus represented ${}_{v}O$, $\overset{v}{O}$, O_{v}.

If three intermediary decrements should occur on the same solid angle, their symbols would also be placed following each other, thus,

(D 3, H 2, F 4,) (D 4, H 3, F 6,) (D 4, H 1, F 3.)

(125.) To denote a decrement on a terminal edge of a doubly oblique prism, the prism is again supposed to be placed or held with that edge nearest to the eye, the plane P continuing horizontal.

If a terminal edge F be replaced by a plane resulting from a decrement by v rows of molecules, it would be denoted by $\overset{v}{F}$, and be read as before, v over F.

If two dissimilar planes occur on the same terminal edge, the symbol is repeated thus $\overset{v}{F}$, $\overset{v'}{F}$, which expresses the coexistence of the two planes on the same edge.

If the lateral edge G or H be modified, the plane M is supposed to be horizontal with the modified edge nearest to the eye, and the decrement is then expressed by the symbol $\overset{v}{G}$ or $\overset{v}{H}$.

All the symbols of simple decrements are thus similar in their form, and distinct from those which represent intermediary decrements.

(126.) The secondary forms of Crystals may be separated into two principal groups:

1. Those which are strictly symmetrical, as *Mod. a, b, c, d, e,* or *f,* of the cube.
2. Those in which the same Modification does not occur on all the similar edges or angles, and which may be subdivided into two classes:
   - *a.* Those in which *each* edge or angle is replaced by only half the number of planes which the law of symmetry requires.
   - *b.* Those in which only the *alternate* edges or angles are modified.

To represent the secondary forms belonging to the first of these groups, it will be sufficient to indicate the character of a single plane belonging to any set of similar planes.

The secondary form of the cube produced by *Mod. b,* fig. 58, or *c,* fig. 59, may be denoted generally by $\overset{v}{A}$. The symbol representing a particular plane of *Mod. c* might be $\overset{\frac{1}{2}}{A}$: and if these symbols be unaccompanied by any other character, they imply that the solid angles are similarly modified.

An intermediary decrement producing any plane of *Mod. d* may be denoted by the general symbol (B_p, B'_q, B''_r).

The planes of *Mod. e* are denoted by $\overset{1}{B}$, and those of *f* by $\overset{v}{B}$.

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It may here be remarked that planes upon the angles of any primary form which in the Tables of Modifications are said to rest upon the primary planes, are produced by decrements, in which the number of molecules in breadth exceeds the number in height; while in those which rest upon the edges, the number in height exceeds the number in breadth. The numbers or fractions expressing the first of these sets will be always greater than unity, as 2, 3, 4, $\frac{3}{2}$, $\frac{4}{3}$, &c.; and those of the latter always less than unity, as $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{4}$, &c.; and the planes in this latter case are carried, as it were, over the solid angle.

(127.) Where an angle or edge of the cube is modified by only *half the number* of planes *d* or *f*, which the law of symmetry requires, the Crystal may be denoted by (0), (B_p, B'_q, B''_r), or (B_p, B'_q, B''_r), (0) according as the plane *d* or *d''* is deficient, the cipher 0 signifying the absence of one of these modifying planes; or, where only one of the pair of planes *f* occurs on an edge of the cube, by $\overset{v}{\underset{0}{B}}$, and if the position of the modifying plane be reversed on the alternate edges, by $\overset{v}{\underset{0}{B}}$, $\overset{0}{\underset{v}{B}}$.

(128.) If only the *alternate* angles are modified by the plane *a*, the symbol would be $\overset{1}{A}$, $\overset{0}{A'}$.

If by the planes *b* or *c*, the symbols might be $\overset{v}{A}$, $\overset{0}{A}$, or A. A' according to the positions of the modified and unmodified angles in the figure 63 whose symbol is $\overset{0}{A}$ $\overset{1}{A'}$.

When *Mod. d* occurs on the alternate angles its symbol might be A (B_p, B'_q, B''_r), A' (0) or A (0), A' (B_p, B'_q, B''_r). But it will be convenient in many cases of defective Modifications to represent the Crystals by figures, in order to avoid the complicated character which the symbols might assume.

(129.) It will be convenient when the secondary forms of Crystals are described by means of these symbols, to observe some certain order in their arrangement into what may be termed the theoretical image of the Crystal; although the particular order in which they are placed is a matter of indifference.

The primary planes may be placed first, and then the different Modifications in the order in which they are given in the Tables, and denoted by the same letters.

Thus if a right rhombic prism should be modified by planes belonging to *a*, *c*, *e*, *h*, and *g*, and also retain portions of the primary planes, the representative symbol might be this,

$$P,\ M,\ \underset{a}{\overset{3}{A}},\ \underset{c}{\overset{2}{E}},\ \underset{e}{\overset{1}{B}},\ \underset{g}{\overset{2}{H}},\ \underset{h}{\overset{1}{G}}.$$

Here the laws of decrement producing the secondary planes are represented by the upper series of symbols, and the lower series consists of the letters on the corresponding modifying planes in the figure of the Crystal.

The relations of these symbols to the several Modifications will be seen in the following Table.

(130.) It may not be useless to remark, that the indices employed in this Treatise to represent planes produced by *intermediary* decrements, are always whole numbers; whereas the symbols used by Haüy to represent similar planes, frequently contain fractional indices.

There is not, however, any real difference in the character of the plane so denoted, by the two methods of representing it.

A particular plane modifying the angle O of the doubly oblique prism would be expressed by Haüy as ($D2\overset{2}{O}F3$), and would be understood to imply that the compound molecules abstracted in the production of the new plane, consisted of smaller compound ones, each being three molecules in height, and two in breadth, repeated twice on the edge D, and three times on the edge E.

It will hence be readily perceived, that if in Haüy's symbol we substitute for the *letter* denoting the *angle* on which the decrement is conceived to take place, *that* which denotes the *edge* upon which that angle may be said to rest, and place the denominator of his fraction after it as its proper index; and if we muliply at the same time his other indices by the numerator of his fraction, the new symbol will be similar in character to those which are contained in this Treatise.

This method of converting the form of the one symbol into that of the other, may be considered general, and by reversing the process, the symbols given in these pages may be converted into the form of those which he has used.

Table of Symbols corresponding to the several Modifications of the Primary Forms.

Table of Symbols corresponding to the several Modifications of the Primary Forms.

(131.) It is evident from what has preceded, that $\overset{1}{A}$ and A_1 must represent the same plane, because a decrement by one row produces a plane that intersects the three adjacent primary planes parallel to their diagonals. But it is convenient to express this decrement by the symbol $\overset{1}{A}$. And hence in the symbol $_vA$ or A_v, v must always be greater or less than 1.

Primary Form.	Symbol.	When v is	Represents Mod.	Represents Plane.
Cube	$\overset{v}{A}$	$= 1$	*a*	*a*
		> 1	*b*	*b*
		< 1	*c*	*o*
	$\overset{v}{B}$	$= 1$	*e*	*e*
		> 1	*f*	*f*
	(B_p, B'_q, B''_r)	....	*d*	*d*
Square prism	$\overset{v}{A}$	any No.	*a*	*a*
	A_v	$>$ or $<$ 1	*b*	$b_{,}$
	$\overset{v}{B}$	any No.	*c*	*c*
	$\overset{v}{G}$	$= 1$	*d*	*d*
		> 1	*e*	*e*
	(B_p, B'_q, G_r)	....	*b*	*b*
Right rhombic prism	$\overset{v}{A}$	any No.	*a*	*a*
	A_v	$>$ or $<$ 1	*b*	$b_{,}$
	$\overset{v}{E}$	any No.	*c*	*c*
	E_v	$>$ or $<$ 1	*d*	$d_{,}$
	$\overset{v}{B}$	any No.	*e*	*e*
	$\overset{v}{H}$	$= 1$	*f*	*f*
		> 1	*g*	*g*
	$\overset{v}{G}$	$= 1$	*h*	*h*
		> 1	*i*	*i*
	(B_p, B'_q, H_r)	....	*b*	*b*
	(B_p, B''_q, G_r)	....	*d*	*d*

Primary Form.	Symbol.	When v is	Represents Mod.	Represents Plane.
Oblique rhombic prism	$\overset{v}{O}$	any No.	a	a
	O_v	$>$ or <1	b	b
	$\overset{v}{A}$	any No.	c	$\dot{c}$
	A_v	$>$ or <1	d	$d_{\prime}$
	$\overset{v}{E}$	any No.	e	$\bar{e}$
	E_v	$>$ or <1	e	$e_{\prime}$
	${}_vE$	$>$ or <1	e	${}_{\prime}e$
	$\overset{v}{D}$	any No.	f	f
	$\overset{v}{B}$	any No.	g	g
	$\overset{r}{H}$	$=1$	h	h
		>1	i	i
	$\overset{v}{G}$	$=1$	k	k
		>1	l	l
	$(D_p\, D'_q\, H'_r)$	....	b	b
	$(B_p\, B'_q \| H_r)$	....	d	d
	$(B'_p\, D_q\, G_r)$	....	e	e
Doubly oblique prism .	$\overset{v}{O}$	any No.	a	$\bar{a}$
	O_v	$>$ or <1	a	$a_{\prime}$
	${}_vO$	$>$ or <1	a	${}_{\prime}a$
	$\overset{v}{A}$	any No.	b	$\bar{b}$
	A_v	$>$ or <1	b	$b_{\prime}$
	${}_vA$	$>$ or <1	b	${}_{\prime}b$
	$\overset{v}{E}$	any No.	c	$\bar{c}$
	E_v	$>$ or <1	c	$c_{\prime}$
	${}_vE$	$>$ or <1	c	${}_{\prime}c$
	$\overset{v}{I}$	any No.	d	$\bar{d}$
	I_v	$>$ or <1	d	$d_{\prime}$
	${}_vI$	$>$ or <1	d	${}_{\prime}d$
	$\overset{v}{D}$	any No.	e	e
	$\overset{v}{C}$	any No.	f	f
	$\overset{v}{B}$	any No.	g	g
	$\overset{v}{F}$	any No.	h	h
	$\overset{v}{H}$	any No.	i	i
	$\overset{v}{G}$	any No.	k	k
	$(D_p\, F_q\, H_r)$	....	a	a
	$(C_p\, B_q\, H'_r)$	....	b	b
	$(B_p\, D_q\, G_r)$	....	c	c
	$(F_p\, C_q\, G'_r)$	....	d	d
Rhomboid	$\overset{v}{A}$	$=1$	a	a
		>1	b	b
		<1	c	c
	$\overset{v}{E}$	$=1$	g	g
		$>$ or <1	h	h
	$\overset{v}{O}$	$=1$	g	g
		$=2$	e	e
		>2	l	l
		<2	i	i
	$\overset{v}{B}$	$=1$	n	n
		>1	o	o
	$\overset{v}{D}$	$=1$	p	p
		>1	q	q
	$(B_p\, B'_q\, B''_r)$	....	d	d
	$(D_p\, D'_q\, B'''_r)$	$\left\{\begin{matrix} p=q\,r \\ q=r+1 \end{matrix}\right\}$	f	f
		$\{p:q:r$ in some other ratio.$\}$	k	k
			m	m

Calculation of the Laws of Decrement.

(132.) The symbols given in the preceding Table express in general terms the Laws of Decrement which produce the several Modifications before described.

To determine the law of any particular plane belonging to any Modification, the particular values of p, q, and r, or of p and r, in relation to such plane, must be found.

It has been shown (42.) that the edges of the *defect* of any primary form are, when the decrement producing it consists of one row of molecules, proportional to the corresponding primary edges, being in all other cases respectively proportional parts of those edges. And the problem of determining the particular values of p, q, and r, is in reality that of finding the proportions of the several primary edges which are cut off by the modifying plane, and which constitute the edges of the defect.

(133.) When the primary edges are unequal, the terminal ones, if equal, may be expressed by m, and the lateral edges by n. When the terminal edges are unequal, as in the doubly oblique prism, one of them may be denoted by m, and the other by o, and the lateral edges by n. When a decrement by one row of molecules produces a new plane, it is evident that $\frac{p}{r}$ will be equal to $\frac{m}{n}$.

When a plane is produced by any other law, the ratio of the edges of the defect will assume the form of $\frac{p\,m}{r\,n}$, and the Law of Decrement $\frac{p}{r}$, or v, is obtained if the ratio of the edges of the defect be divided by the ratio of the corresponding primary edges.

But the Law of Decrement may in particular cases be more conveniently determined from the ratio of an edge to some other line which would be proportionally intercepted by the modifying plane, and which may, when necessary, be denoted by l.

31.) The following is a general method of discovering the Law of Decrement, by which any new plane has been produced upon any primary form.

To ascertain the ratio of $i\,b$ to $i\,c$, fig. 125, being the edges of the *defect* produced by a decrement on an edge of any parallelopiped, the inclination of the primary planes to each other being known, and also the inclination of the modifying plane $a\,b\,c\,f$ to the primary planes P and T, the angles of the plane triangle $i\,b\,c$ are required.

These may be obtained by means of a spherical triangle, whose angle A is the supplement of the inclination of P on the plane $a\,b\,c\,f$, B the inclination of P on T, and C the supplement of the inclination of T on $a\,b\,c\,f$.

From this spherical triangle the side a containing the required angle $i\,b\,c$ may be deduced from the known formula,

$$\sin \tfrac{1}{2} a = \mathrm{R}\left(\frac{-\cos \frac{1}{2}(A+B+C) \, . \, \cos \frac{1}{2}(B+C-A)}{\sin B \, . \, \sin C}\right)^{\frac{1}{2}}$$

and by applying the same formula to a second spherical triangle, whose angle

C is similar to that of the preceding,

B is the inclination of M on T,

A the supplement of M on $a\,b\,c\,f$.

derived from actual measurement, or deduced from its

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known inclination on P, and of P on M, the side a, which contains the other required angle $i\ c\ b$, may be obtained.

Having thus determined the two plane angles, $i\ b\ c$, $i\ c\ b$, the ratio of $i\ b$ to $i\ c$ is known from the relation of the sines of the angles of triangles to the sides subtending those angles, thus,

$$i\ b : i\ c :: \sin i\ c\ b : \sin i\ b\ c.$$

If the new plane has resulted from a decrement on the edge $h\ i$, by one row of molecules, the lines $i\ b$, $i\ c$, must be to each other as m to n, and then

$$\sin i\ c\ b : \sin i\ b\ c :: m : n.$$

But if the new plane has resulted from a decrement by unequal numbers in breadth and in height, the ratio of $i\ b$ to $i\ c$ will be as $p\ m$ to $r\ n$, p representing the number of molecules abstracted in the direction $i\ k$, and r the number in the direction $i\ d$; and dividing this ratio by $\frac{m}{n}$, a Law of Decrement is given of p rows in breadth, or in the direction of $i\ k$, and q in height, or in the direction of the edge $i\ d$.

(135.) The ratios of the three edges, $i\ b$, $i\ c$, $i\ a$, fig. 126, intercepted by a decrement on one of the angles of a parallelopiped, may be thus determined.

The inclination of the primary planes to each other being known, the three plane angles at i may be deduced by means of a spherical triangle; and having measured the inclination of the plane $a\ b\ c$ on P, M, and T, the plane angles at a, b, and c may be discovered by means of two spherical triangles, whose angles are those at which the primary planes incline to each other, and the supplements of those at which the secondary plane inclines on the adjacent primary planes.

The plane angles at a, b, and c, being found, the Law of Decrement may be determined from the ratios of $i\ b : i\ c$ and $i\ b : i\ a$.

Let	$i\ k : i\ d :: m : n,$
and	$i\ k : i\ h :: m : o,$
and let	$i\ b : i\ c :: p\ m : r\ n,$
	$i\ b : i\ a :: p\ m : q\ o.$

After dividing $\frac{p\ m}{r\ n}$ by $\frac{m}{n}$, and $\frac{p\ m}{q\ o}$ by $\frac{m}{o}$,

we find
$$i\ b = p,$$
$$i\ a = q,$$
$$i\ c = r,$$

implying a decrement by p molecules in the direction of $i\ k$, q in that of $i\ h$, and r in that of $i\ d$.

If fig. 126 be a doubly oblique prism, and the edges $i\ h$, $i\ k$, $i\ d$, be respectively denoted by D, F, H, the symbol of the plane, $a\ b\ c$, would be ($F_p\ D_q\ H_r$).

By this general method, when the inclinations of the primary planes to each other are known, and also that of the secondary plane on one or more of the primary, the Law of Decrement may be found by which any secondary plane has been produced on any primary form.

But as it will appear in the sequel, the methods of determining this law become much more simple in reference to several of the primary forms.

It may not be useless again to observe, that when a Law of Decrement producing any plane is to be determined, its *general symbol* is first to be found in the preceding Tables, and then the *particular values* of its *indices* are to be determined.

In simple decrements, these values may be deduced from some simple ratio, as that of radius to tangent, or of sin a to sin b, and the following may be regarded as the general process for determining the law of an intermediary decrement.

Calculation of the Laws of Decrement.

1. To measure the inclination of the secondary planes on two of the adjacent primary planes.
2. To determine the two plane angles at the termination of the greater edge of the *defect* of the primary form occasioned by the secondary plane.
3. From a knowledge of these plane angles, and of the plane angles of the primary planes, to deduce the ratios of the edges of the *defect*.
4. To divide these ratios by the ratios of the corresponding edges of the primary form, and thus to deduce the Law of Decrement.

(136.) From what has preceded it will be readily perceived that the ratios of the primary edges of Crystals may be determined, by assuming some observed secondary plane replacing an edge of those forms whose terminal edges are equal, or replacing an angle of those whose terminal edges are unequal, to have been produced by some given Law of Decrement. If by *one* row of molecules the ratio of the primary edges corresponds to that of the *edges* of the *defect* occasioned by such plane. And if any other law be assumed, the ratios of the primary edges may evidently be determined, from the division of the ratios of the edges of the defect by the assumed Law of Decrement.

(137.) In the methods about to be given of determining the Laws of Decrement in relation to each of the primary forms, a *single* reference only is given in each case to the figures contained in the Tables of Modifications, and to one or two other explanatory ones. This has been done to avoid the confusion of perpetual references to different figures. And it is to be understood that whenever the *inclination* of *two planes* is given, as P,a, P,b, &c. *these letters* refer to the *Tables of Modifications;* and whenever any *lines or plane angles* are referred to as line $a\ b$, or angle $a\ b\ c$, *these will be found on the explanatory figures.*

(138.) The inclination of the primary planes, the ratios of the primary edges, &c., are termed the *crystallographical elements* of the primary form.

It will be found particularly convenient in examining and describing Crystals, to determine these elements in the first instance for each particular substance, so as to have them ready for computing the Laws of Decrement of the modifying planes.

The formulæ given for this purpose are generally derived from spherical trigonometry, and are in most instances so easily deduced as to render demonstration unnecessary. And as the division by $\frac{m}{n}$ or $\frac{l}{n}$ is already effected in these, they immediately give the value to be substituted for $\frac{p}{r}$ or its equivalent v in the general symbol.

The reader will thus have before him, Tables of all the groups of forms which can result from regular Crystallization; Tables of the *Laws of Decrement* expressed in *general terms*, by which the modifying planes of these groups might be respectively produced; and the means of determining the *particular* law from which any *individual plane* of *either* of these *groups* might result.

Some other relations among primary and secondary forms will also be pointed out.

THE CUBE.

Fig. 56 to 64, and 127.

Crystallographical Elements.

(139.) Inclination of any two adjacent planes = 90°.
Plane angles = 90°.
Edges equal.
Inclination of an edge to an oblique axis = 54° 44′ 8″.

(140.) Ratio of half a diagonal to an edge.

$$h\,f : f\,c :: 1 : \sqrt{2}.$$

(141.) Ratio of an edge to an oblique axis,

$$f\,c : c\,g :: 1 : \sqrt{3}.$$

Simple Decrements on the Angles producing planes b. and c.

General symbol $\dot{A}$

(142.) $$v = \frac{R\sqrt{2}}{\tan(180° - P,b)}.$$

(143.) $$= \frac{R\sqrt{2}}{\tan(180° - P,c)},$$

(144.) The expression $\tan(180° - P,b)$ is used instead of $-\tan P,b$ to point out more clearly the derivation of the given angle; an observation which will apply to future similar expressions of this and other trigonometrical lines.

(145.) It is evident that $h\,f$, half the diagonal $g\,f$, is intercepted at the point h by the edge $a\,b$ of a secondary plane resulting from a decrement by one row of molecules, and would be intercepted, proportionally to the edges, by any other law. It is therefore used instead of an edge for expressing the Laws of Decrement producing the planes b and c.

Decrements on the Edges.

General symbol $\dot{B}$.

(146.) $$c = \frac{R}{\tan(180° - P,f)}.$$

Intermediary Decrements.

The general symbol representing a plane of *Mod. d* is $(B_p\, B'_r\, B''_r)$.

(147.) $$\cos k\,i\,f = \frac{R.\cos(180° - P',d)}{\sin(180° - P,d)}.$$

(148.) $$\cos f\,i\,d = \frac{R.\cos(180° - P,d)}{\sin(180° - P',d)}.$$

Two plane angles of the defect being thus found, we have,

$$i\,f : f\,k :: R : \tan k\,i\,f :: p : q,$$
$$i\,f : f\,d :: R : \tan f\,i\,d :: p : r.$$

(149.) When any of the modifying planes, b, c, d, or f, occur upon the tetrahedron, octahedron, or rhombic dodecahedron, their respective inclinations to the planes of the cube must be inferred from the angles at which some of them incline to each other.

The positions of such planes upon the tetrahedron, the octahedron, and rhombic dodecahedron may be readily found from their relation to the Modifications which produce those forms.

Thus, $$P,b = 305° 15' 52'' - b,a$$
$$= 270° - b,e''$$
$$P,e'' = a,e'' - 54° 44' 8'$$
$$= 270° - e',e''$$
$$P,f = 225° - \tfrac{1}{2} f,f'.$$

THE SQUARE PRISM.

Fig. 65 to 70, and 128.

Crystallographical Elements

(150.) Inclination of any two adjacent planes = 90°.
Plane angles = 90°.
Terminal edges equal.
Lateral edges equal.

(151.) Ratio of terminal to lateral edge,

$$d\,a : a\,f :: m : n.$$

(152.) Ratio of terminal edge to half diagonal of terminal plane,

$$d\,a : a\,b :: \sqrt{2} : 1.$$

(153.) Ratio of half diagonal of terminal plane to lateral edge,

$$a\,b : a\,f :: \frac{m}{\sqrt{2}} : n.$$

(154.) Ratio of terminal edge to perpendicular upon diagonal $e\,f$,

$$d\,a : a\,c :: m : \frac{m\,n}{(m^2 + n^2)^{\frac{1}{2}}}$$

(155.) $$\tan a\,e\,f = \frac{R\,n}{m}$$

$$a\,e : a\,f :: m : n :: R : \tan a\,e\,f.$$

(156.) The ratio, $m : n$ of the primary edges can be determined only from the inclination of the primary to some secondary plane, assumed to be produced by a given Law of Decrement.

If a or c be assumed to have resulted from a decrement by one row of molecules, the ratio of the edges of the defect occasioned by either of these planes must, as already explained, correspond to that of the primary edges. If some other Law of Decrement be assumed, the ratio of the edges of the defect must then be divided by that law to obtain the ratio of the primary edges.

After the explanations already afforded of the methods employed for discovering the Laws of Decrement, it does not appear necessary in future to do more than to give the *general* symbol of each of the Modifications, and the formulæ by which the *particular* values of p, q, and r, in each symbol, are to be deduced.

Simple Decrements on the Angles.

General symbols $\dot{A}$, $A_{\prime\prime}$.

(157.) $A_{\prime\prime}$ $$v = \frac{n\,R\sqrt{2}}{m.\tan(180° - P,a)}.$$

This formula expresses the ratio of the whole lateral edge to its defect, and also the *numerical* ratio of half a terminal diagonal to the same defect.

(158.) $\dot{A}$, $$v = \frac{(m^2 + n^2)^{\frac{1}{2}} R}{n.\tan(180° - M,b)}.$$

Decrements on the Edges.

General symbols $\dot{B}$, $\dot{G}$.

(159.) $\ddot{B}$, $$v = \frac{n\,R}{m.\tan(180° - P,c)}.$$

(160.) $\overset{v}{\mathrm{G}}$, $\quad r = \dfrac{\mathrm{R}}{\tan(180^\circ - \mathrm{M},c)}$.

If $v = 1$ in (157.) or (159.) the ratio of the primary edges may be immediately obtained.

Intermediary Decrements.

(161.) $\quad \cos i\,g\,a = \dfrac{\mathrm{R}\,.\,\cos(180^\circ - \mathrm{M},b)}{\sin(180^\circ - \mathrm{P},b)}$.

(162.) $\quad \cos a\,g\,k = \dfrac{\mathrm{R}\,.\,\cos(180^\circ - \mathrm{P},b)}{\sin(180^\circ - \mathrm{M},b)}$.

Whence $\quad a\,g : a\,i :: \mathrm{R} : \tan i\,g\,a :: p : q,$

$\qquad\quad a\,g : g\,k :: \mathrm{R} : \tan a\,g\,k :: p : r.$

In the examination of Crystals it is frequently necessary to ascertain the inclination of particular planes which cannot be measured, by means of known angles; or to determine the inclinations of planes in particular directions from their known angles in other directions. For which purposes the following formulæ will be found useful:

$$\mathrm{P},a = 180^\circ - \tfrac{1}{2}\,a',a''.$$

(163.) $\quad \sin\tfrac{1}{2}\,a',a'' = \sqrt{2}\,.\,\cos\tfrac{1}{2}\,a,a'$
$\qquad\qquad = \cos\tfrac{1}{2}\,a,a''.$

The same relations subsist between c,c', c,c'', and c,c'''.

The plane angle at the base of an octahedron derived from *Mod. a* or *c* being denoted by r may be thus found:

(164.) $\quad \cos r = \dfrac{\mathrm{R}\,.\,\cot\frac{1}{2}\,c',c'''}{\tan\frac{1}{2}\,c,c'}$.

(165.) From the preceding equations,

$$\frac{\mathrm{R}\,\sqrt{2}}{\tan(180^\circ - \mathrm{P},a)} = \frac{\mathrm{R}}{\tan(180^\circ - \mathrm{P},c)};$$

(166.) Whence

$$\tan(180^\circ - \mathrm{P},a) = \sqrt{2}\,.\,\tan(180^\circ - \mathrm{P},c).$$

This relation obviously subsists between the planes whose indices are $\overset{v}{\mathrm{A}}$ and $\overset{v}{\mathrm{B}}$, whenever v is the same in both.

(167.) And if v be equal in equations 2 and 5, we have

$$\frac{n\,\mathrm{R}\,\sqrt{2}}{m\,.\,\tan(180^\circ - \mathrm{P},a)} = \frac{\mathrm{R}\,(m^2 + n^2)^{\frac{1}{2}}}{n\,.\,\tan(180^\circ - \mathrm{M},b)}.$$

(168.) Whence $\tan\mathrm{P},a = \tan\mathrm{M},b\,\dfrac{n^2\sqrt{2}}{m\,(m^2 + n^2)^{\frac{1}{2}}}$.

(169.) And, $\quad \tan\mathrm{P},c = \tan\mathrm{M},b\,\dfrac{n^2}{m\,(m^2 + n^2)^{\frac{1}{2}}}$.

(170.) If, in equation 2, $v = 1$, and in 5, $v = \dfrac{p}{r}$,

then $\quad \dfrac{n\,\mathrm{R}\,\sqrt{2}}{m.\tan(180^\circ - \mathrm{P},a)} = \dfrac{r\,\mathrm{R}\,(m^2 + n^2)^{\frac{1}{2}}}{p\,n\,.\,\tan(180^\circ - \mathrm{M},b)}$.

(171.) Whence $\tan\mathrm{P},a = \tan\mathrm{M},b\,\dfrac{p\,n^2\sqrt{2}}{r\,m\,(m^2 + n^2)^{\frac{1}{2}}}$.

It may be remarked that a regular eight-sided pyramid the planes of which are isosceles triangles, cannot be produced on the square prism by any regular Law of Decrement.

THE RIGHT RHOMBIC PRISM.

Fig. 71 to 82, and 129.

Crystallographical Elements.

(172.) Inclination of terminal to lateral planes $= 90^\circ$.
Inclination of lateral planes differs in different minerals. The greater angle is denoted by M,M′.
Terminal plane angles correspond to angles of prism.
Lateral plane angles $= 90^\circ$.
Terminal edges equal.
Lateral edges equal.

(173.) Ratio of terminal to lateral edge,

$$e\,f : e\,m :: m : n.$$

(174.) Ratio of terminal edge to half lesser diagonal of terminal plane,

$$e\,f : f\,n :: \mathrm{R} : \cos\tfrac{1}{2}\,\mathrm{M},\mathrm{M}'$$
$$:: m : \frac{m\,.\,\cos\frac{1}{2}\,\mathrm{M},\mathrm{M}'}{\mathrm{R}}.$$

(175.) Ratio of terminal edge to half greater diagonal of terminal plane,

$$e\,f : e\,n :: \mathrm{R} : \sin\tfrac{1}{2}\,\mathrm{M},\mathrm{M}'$$
$$:: m : \frac{m\,.\,\sin\frac{1}{2}\,\mathrm{M},\mathrm{M}'}{\mathrm{R}}.$$

(176.) Ratio of half lesser diagonal of terminal plane to lateral edge,

$$n\,f : f\,l :: \frac{m\,.\,\cos\frac{1}{2}\,\mathrm{M},\mathrm{M}'}{\mathrm{R}} : n.$$

(177.) Ratio of half greater diagonal of terminal plane to lateral edge,

$$n\,e : e\,m :: \frac{m\,.\,\sin\frac{1}{2}\,\mathrm{M},\mathrm{M}'}{\mathrm{R}} : n.$$

(178.) Ratio of $f\,g$ (perpendicular on $i\,k$) to lateral edge,

$$f\,g : f\,l :: \frac{m\,.\,\cos(\mathrm{M},\mathrm{M}' - 90^\circ)}{\mathrm{R}} : n.$$

(179.) The angle $f\,k\,l$ may be found from the equation

$$\tan f\,k\,l = \frac{n\,\mathrm{R}}{m}.$$

Simple Decrements on the Terminal Angles.

(180.) $\overset{v}{\mathrm{A}}$, $\quad v = \dfrac{n\,\mathrm{R}^2}{m\,.\cos\frac{1}{2}\,\mathrm{M},\mathrm{M}'\,.\,\tan(180^\circ - \mathrm{P},a)}$.

(181.) $\overset{v}{\mathrm{E}}$, $\quad v = \dfrac{n\,\mathrm{R}^2}{m\,.\sin\frac{1}{2}\,\mathrm{M},\mathrm{M}'\,.\,\tan(180^\circ - \mathrm{P},c)}$.

Decrements on the Edges.

(182.) $\overset{v}{\mathrm{B}}$, $\quad v = \dfrac{n\,\mathrm{R}^2}{m\,.\cos(\mathrm{M},\mathrm{M}' - 90^\circ)\,.\,\tan(180^\circ - \mathrm{P},e)}$.

(183.) $\overset{v}{\mathrm{H}}$, $\quad v = \dfrac{\sin(180^\circ - \mathrm{M},g)}{\sin(\mathrm{M},g - \mathrm{M},\mathrm{M}')}$.

(184.) $\overset{v}{\mathrm{G}}$, $\quad v = \dfrac{\sin(180^\circ - \mathrm{M},i)}{\sin(\mathrm{M},i + \mathrm{M},\mathrm{M}' - 180^\circ)}$.

(185.) If, in the general formula for $\overset{v}{\mathrm{A}}$, we make $v = 1$,

$$\frac{m}{n} = \frac{\mathrm{R}^2}{\sin\frac{1}{2}\,\mathrm{M},\mathrm{M}'\,.\,\tan(180^\circ - \mathrm{P},a)}$$

which gives the ratio of the primary edges; or it may

be derived in a similar manner from the formulæ for $\overset{v}{E}$ or $\overset{v}{B}$ by making $v = 1$, and then dividing both sides of the equation by n and multiplying by m.

Simple Decrements corresponding to the Symbols A_v *and* E_v, *and Intermediary Decrements.*

(186.) $\cos b\,a\,f = \dfrac{R\,.\,\cos(180^\circ - M,b)}{\sin(180^\circ - P,b)}$.

(187.) $\cos f\,a\,c = \dfrac{R\,.\,\cos(180^\circ - P,b)}{\sin(180^\circ - M,b)}$.

(188.) $fa : fb :: \sin(180^\circ - M,M' - b\,a\,f) : \sin b\,a\,f$,

$$:: n\,R : \frac{n\,R\,.\,\sin b\,a\,f}{\sin(180^\circ - M,M' - b\,a\,f)},$$

$$:: p : q :$$

(189.) $fa : fc :: R : \tan f\,a\,c$

(190.) In relation to *Mod. d*,

$$\cos u\,v\,e = \frac{R\,.\,\cos M,d}{\sin P,d}$$

(191.) $\cos e\,v\,w = \dfrac{R\,.\,\cos P,d}{\sin M,d}$,

Whence

(192.) $ve : eu :: \sin(M,M' - u\,v\,e) : \sin u\,v\,e$,

$$:: n\,R : \frac{n\,R\,.\,\sin u\,v\,e}{\sin(M,M' - u\,v\,e)},$$

$$:: p : q :$$

(193.) $ev : cw :: m\,R : n\,.\,\tan e\,v\,w$,

$$:: p : r.$$

If the angle $f\,a\,c$ or $e\,v\,w$, deduced from either of the preceding formulæ, be equal to the angle $f\,e\,l$, or $e\,f\,m$, the plane to which it relates has for its symbol A or E, and the edges of the defect corresponding to $e\,f$, $f\,l$, or $e\,f$, $e\,m$, must be in the ratio of m to n, and hence the ratio of the third edge to either of these determines the Law of Decrement.

(194.) The following formula may be useful in examining Crystals:

$$\sin \tfrac{1}{2} M,M' = R\,\frac{\cos \frac{1}{2}\,e',e''}{\sin \frac{1}{2}\,e',e'''}.$$

And it may be observed that the planes of *Mod. i* can never meet at an angle equal to M,M′, unless M,M′ = 120°.

THE OBLIQUE RHOMBIC PRISM.

Fig. 83 to 94, and 130.

Crystallographical Elements.

(195.) Inclination of terminal to lateral planes varies in different minerals.

Inclination of lateral planes varies in different minerals, and M,M′ may be either acute or obtuse.

(196.) Terminal and lateral plane angles may be thus ound:

$$\cos \tfrac{1}{2} f\,a\,d = \frac{R\,.\,\cos \frac{1}{2} M,M'}{\sin P,M}.$$

(197.) $\cos f\,a\,e = \dfrac{\cot P,M\,.\,\cot \frac{1}{2} M,M'}{R}$.

Terminal edges equal.

Lateral edges equal.

(198.) Ratio of terminal to lateral edge,

$$fa : fm :: m : n.$$

(199.) Inclination of oblique diagonal $g\,a$ to oblique edge $a\,e$ may be thus found:

$$\cos g\,a\,e = \frac{R\,.\,\cos P,M}{\sin \frac{1}{2} M,M'}.$$

(200.) Ratio of terminal edge to half oblique diagonal,

$$af : ah :: R : \cos \tfrac{1}{2} f\,a\,d.$$

$$:: m : \frac{m\,.\,\cos \frac{1}{2} f\,a\,d}{R}$$

$$:: \sin P,M : \cos \tfrac{1}{2} M,M'$$

$$:: m : \frac{m\,.\,\cos \frac{1}{2} M,M'}{\sin P,M}.$$

(201.) Ratio of terminal edge to half horizontal diagonal,

$$af : fh :: R : \sin \tfrac{1}{2} f\,a\,d$$

$$:: m : \frac{m\,.\,\sin \frac{1}{2} f\,a\,d}{R}$$

$$:: m : \frac{m\{(\sin P,M)^2 - (\cos \frac{1}{2} M,M')^2\}^{\frac{1}{2}}}{\sin P,M}.$$

(202.) For $(\sin \tfrac{1}{2} f\,a\,d)^2 = R^2 - (\cos \tfrac{1}{2} f\,a\,d)^2$

$$= R^2 - \frac{R^2 (\cos \frac{1}{2} M,M')^2}{(\sin P,M)^2},$$

$$= \frac{R^2\{(\sin P,M)^2 - (\cos \frac{1}{2} M,M')^2\}}{(\sin P,M)^2};$$

(203.) $\therefore \dfrac{\sin \frac{1}{2} f\,a\,d}{R} = \dfrac{\{(\sin P,M)^2 - (\cos \frac{1}{2} M,M')\}^{\frac{1}{2}}}{\sin P,M}$.

(204.) Ratio of half oblique diagonal to lateral edge,

$$ah : ae :: \frac{m\,.\,\cos \frac{1}{2} f\,a\,d}{R} : n,$$

$$:: \frac{m\,.\,\cos \frac{1}{2} M,M'}{\sin P,M} : n.$$

(205.) Ratio of half horizontal diagonal to lateral edge,

$$fh : fm\,(= ae) :: \frac{m\,.\,\sin \frac{1}{2} f\,a\,d}{R} : n.$$

(206.) $:: \dfrac{m\{(\sin P,M)^2 - (\cos \frac{1}{2} M,M')^2\}^{\frac{1}{2}}}{\sin P,M} : n.$

(207.) Ratio of half horizontal diagonal to fr perpendicular to $r\,m$,

$$fh : fm :: m\,.\,\sin \tfrac{1}{2} f\,a\,d : n\,R,$$

$$fm : fr :: R : \cos(g\,a\,e - 90^\circ),$$

$$:: n\,R : n\,.\,\cos(g\,a\,e - 90^\circ),$$

(208.) $fh : fr :: m\,.\,\sin \tfrac{1}{2} f\,a\,d : n\,.\,\cos(g\,a\,e - 90^\circ)$.

(209.) The angles $f\,a\,m$ and $f\,m\,a$ may be thus found:

Let S = their sum $= f\,a\,e$,

D = their difference,

$s = m + n$, the sum of the sides containing $f\,a\,e$ or $m\,f\,a$,

$d = m - n$, their difference,

$$\tan \tfrac{1}{2} D = \frac{d\,.\,\tan \frac{1}{2} S}{s},$$

$\frac{1}{2} S + \frac{1}{2} D$ = greater angle,

$\frac{1}{2} S - \frac{1}{2} D$ = lesser angle,

and the greater angle will be subtended by the greater edge of the prism.

(210.) Ratio of ab, perpendicular to gd, to ac, perpendicular to me,

$$ab : ad :: \cos(fad - 90^\circ) : \mathrm{R},$$
$$:: \frac{m.\cos(fad-90^\circ)}{\mathrm{R}} : m,$$
$$ad : ae :: \quad m \quad : n,$$

(211.) $ae : ac :: \quad \mathrm{R} \quad : \cos(fae - 90^\circ)$,

(212.) $\therefore ab : ac :: m.\cos(fad-90^\circ) : n.\cos(fac-90^\circ)$.

When fad is an acute angle,

(213.) $ad : ab' :: \mathrm{R} : \cos(90^\circ - fad)$
$$:: \mathrm{R} : \sin fad.$$

(214.) Hence $ab' : ac :: m.\sin fad : n.\cos(fac-90^\circ)$.

Simple Decrements on the Terminal Angles.

(215.) $\overset{n}{\mathrm{O}}, \quad v = \dfrac{n\,\mathrm{R}.\sin(\mathrm{P},a - hac)}{m.\cos\frac{1}{2}fad.\sin(180^\circ - \mathrm{P},a)}$.

(216.) $\overset{n}{\mathrm{A}}, \quad v = \dfrac{n\,\mathrm{R}.\sin(\mathrm{P},c' + hac - 180^\circ)}{m.\cos\frac{1}{2}fad.\sin(180^\circ - \mathrm{P},c')}$.

(217.) $\overset{n}{\mathrm{E}}, \quad v = \dfrac{n\,\mathrm{R}.\cos(gae - 90^\circ)}{m.\sin\frac{1}{2}fad.\tan(180^\circ - \mathrm{P},e)}$.

Decrements on the Edges.

When $\mathrm{M,M'} > 90^\circ$,

(218.) $\overset{n}{\mathrm{D}}, v = \dfrac{n.\cos(fae-90^\circ).\sin(\mathrm{P},f - \mathrm{P,M})}{m.\cos(fad-90^\circ).\sin(180^\circ - \mathrm{P},f)}$.

(219.) $\overset{n}{\mathrm{B}}, v = \dfrac{n.\cos(fae-90^\circ).\sin(\mathrm{P},g + \mathrm{P,M} - 180^\circ)}{m.\cos(fad-90^\circ).\sin(180^\circ - \mathrm{P},g)}$.

When $\mathrm{M,M'} < 90^\circ$,

(220.) $\overset{n}{\mathrm{D}}, v = \dfrac{n.\cos(fae-90^\circ).\sin(\mathrm{P},f - \mathrm{P,M})}{m.\sin fad.\sin(180^\circ - \mathrm{P},f)}$.

(221.) $\overset{n}{\mathrm{B}}, v = \dfrac{n.\cos(fae-90^\circ).\sin(\mathrm{P},g + \mathrm{P,M} - 180^\circ)}{m.\sin fad.\sin(180^\circ - \mathrm{P},g)}$.

If $\mathrm{M,M'} >$ or $< 90^\circ$,

(222.) $\overset{n}{\mathrm{H}}, \quad v = \dfrac{\sin(\mathrm{M}',i' - \mathrm{M,M'})}{\sin(180^\circ - \mathrm{M}',i')}$.

(223.) $\overset{n}{\mathrm{G}}, \quad v = \dfrac{\sin(\mathrm{M},l + \mathrm{M,M'} - 180^\circ)}{\sin(180^\circ - \mathrm{M},l)}$.

It is evident that if $v = 1$ in any of the preceding formulæ except the two last, the ratio of m to n may be immediately obtained.

Simple Decrements upon the Lateral Angles, and Intermediary Decrements.

(224.) Let the defect occasioned by a given plane be regarded as a spherical triangle, the angles of which are

$$\mathrm{A} = 180^\circ - \mathrm{P},b$$
$$\mathrm{B} = \mathrm{P,M}$$
$$\mathrm{C} = 180^\circ - \mathrm{M},b.$$

The side c may be obtained from the formula

$$\sin\tfrac{1}{2}c = \mathrm{R}\left(\frac{-\cos\frac{1}{2}(\mathrm{A+B+C}).\cos\frac{1}{2}(\mathrm{A+B-C})}{\sin \mathrm{A}.\sin \mathrm{B}}\right)^{\frac{1}{2}},$$

and the side a from another corresponding to it.

If the side a be equal to the angle afe its intersection with M will be parallel to a diagonal fe of that plane, and its symbol will then be $\mathrm{O}_{,}$, and the ratio of the edges of the defect corresponding to the *terminal* edges of the prism will give the Law of Decrement. But if b do not intersect M parallel to a diagonal, the symbol of the measured plane is $(\mathrm{D}_{,}\mathrm{D}'_{,}\mathrm{H}_{,})$ and the ratios of the three edges of the defect must be found by the general method already explained.

Similar observations may be applied to the planes d whose symbol is either A, or $(\mathrm{B}_{,}\mathrm{B}'_{,}\mathrm{H}'_{,})$, and to those planes e whose symbol is ${}_{,}\mathrm{E}$, or $\mathrm{E}_{,,}$ or $(\mathrm{B}'_{,}\mathrm{D}_{,}\mathrm{G}_{,})$.

A repetition of the formulæ for these cases is unnecessary after the explanation already given, but it may be convenient to have the angles of the spherical triangles for determining the indices of those planes.

(225.) For d, $\quad \mathrm{A} = 180^\circ - \mathrm{P},d$
$$\mathrm{B} = 180^\circ - \mathrm{P,M}$$
$$\mathrm{C} = 180^\circ - \|\mathrm{M},d;$$

for e, where its symbol is ${}_{,}\mathrm{E}$,

(226.) $\quad \mathrm{A} = 180^\circ - \mathrm{P},e$
$$\mathrm{B} = 180^\circ - \mathrm{P,M}$$
$$\mathrm{C} = 180^\circ - \|\mathrm{M}',e;$$

where its symbol is $\mathrm{E}_{,,}$

(227.) $\quad \mathrm{A} = 180^\circ - \mathrm{P},e$
$$\mathrm{B} = \mathrm{P,M}$$
$$\mathrm{C} = 180^\circ - \mathrm{M},e:$$

and *either* of these two latter sets of angles may be used where the symbol is $(\mathrm{B}'_{,}\mathrm{D}_{,}\mathrm{G}_{,})$.

THE DOUBLY OBLIQUE PRISM.

Fig. 95 to 105, and fig. 131.

Crystallographical Elements.

(228.) Inclination of terminal to lateral planes is different in different minerals, and P,M differs also from P,T.

Inclination of lateral planes M,T varies in different minerals.

In the figure, and in the following remarks, P,M, P,T, M,T are all supposed greater than 90°, and the edges D, F, and H are consequently obtuse edges.

Terminal and lateral plane angles may be obtained from a spherical triangle of which the angles are

(229.) $\quad \mathrm{A} = \mathrm{P,M}$
$$\mathrm{B} = \mathrm{P,T}$$
$$\mathrm{C} = \mathrm{M,T};$$

and of which the sides are

$$a = caf$$
$$b = baf$$
$$c = bac.$$

Terminal edges B and C unequal, B and F equal, C and D equal.

Lateral edges equal.

(230.) Ratio of terminal edge D to lateral edge,
$$ab : af :: m : n.$$

(231.) Ratio of terminal edge F to lateral edge,
$$ac : af :: o : n;$$

whence $\mathrm{D} : \mathrm{F} :: m : o$.

To obtain the ratios of $m : n$ and of $o : n$, let

$b\,e$, $e\,f$, $b\,f$, be the edges of a plane a whose symbol is $\overset{i}{O}$.

(232.) A spherical triangle whose angles are

$$A = 180^\circ - P,a$$
$$B = P,T,$$
$$C = 180^\circ - T,a,$$

will give the side $c = a\,e\,b$
$$a = a\,e\,f;$$

whence as $b\,a\,e$ and $e\,a\,f$ are known, the angles $e\,b\,a$ and $e\,f\,a$ are known, and hence the ratios of the edges may be found.

(233.) The plane angles $a\,b\,f$ and $a\,f\,b$ may also be deduced from another spherical triangle whose angles are

$$A = 180 - P,a$$
$$B = P,M$$
$$C = 180 - M,a.$$

(234.) Ratio of $b\,a$ perpendicular on $b\,d$ to $a\,l$, perpendicular on $f\,g$,

$a\,h : a\,b :: \cos(b\,a\,e - 90^\circ) : R.$

(235.) $:: m \,.\, \cos(b\,a\,e - 90^\circ) : m\,R,$

and $a\,f : a\,l ::$ $\quad n\,R$ $\quad : n\,.\cos(e\,a\,f - 90^\circ),$

but $a\,b : a\,f ::$ $\quad m$ $\quad : n.$

(236.) $a\,h : a\,l :: n\,.\cos(b\,a\,e - 90^\circ) : n\,.\cos(e\,a\,f - 90^\circ).$

In the same manner it may be shown that

(237.) $a\,i : a\,k :: o\,.\cos\,.(b\,a\,e - 90^\circ) : n\,.\cos(b\,a\,f - 90^\circ).$

(238.) $a\,n : a\,r :: m\,.\cos(b\,a\,f - 90^\circ) : o\,.\cos(e\,a\,f - 90^\circ).$

Decrements on the Angles.

By a method analogous to that used for determining the ratios of the primary edges, the ratios of the edges of the defect occasioned by any Law of Decrement on an angle may be obtained; and these being divided by the ratios of the primary edges will give the Law of Decrement. If an edge of any plane belonging to *Mod.* a or b, or c, or d, be parallel to a diagonal of a primary plane it will result from a simple decrement, and its symbol will be $_{n}A$, $\overset{n}{A}$, or A_n, $_nE$, $\overset{n}{E}$ or E_n, $_nI$, $\overset{n}{I}$ or I_n, $_nO$, $\overset{n}{O}$ or O_n, according to the situation of the primary plane to whose diagonal its edge is parallel.

Decrements on the Edges.

(239.) $$\overset{n}{B},v = \frac{n\,.\cos(e\,a\,f - 90^\circ)\,.\sin(T,g + P,T - 180^\circ)}{m\,.\cos(b\,a\,e - 90^\circ)\,.\sin(180^\circ - P,g)}.$$

(240.) $$\overset{n}{C},v = \frac{n\,.\cos(b\,a\,f - 90^\circ)\,.\sin(P,f + P,M - 180^\circ)}{o\,.\cos(b\,a\,e - 90^\circ)\,.\sin(180^\circ - P,f)}.$$

(241.) $$\overset{n}{D},v = \frac{n\,.\cos(b\,a\,f - 90^\circ)\,.\sin(P,e - P,M)}{o\,.\cos(b\,a\,e - 90^\circ)\,.\sin(180^\circ - P,e)}.$$

(242.) $$\overset{n}{F}\,v = \frac{n\,.\cos(e\,a\,f - 90^\circ)\,.\sin(P,h - P,T)}{m\,.\cos(b\,a\,e - 90^\circ)\,.\sin(180^\circ - P,h)}.$$

(243.) $$\overset{n}{G},v = \frac{o\,.\cos(e\,a\,f - 90^\circ)\,.\sin(180^\circ - T,k)}{m\,.\cos(b\,a\,f - 90^\circ)\,.\sin(180^\circ - M,k)}.$$

(244.) $$\overset{n}{H},v = \frac{m\,.\cos(b\,a\,f - 90^\circ)\,.\sin(180^\circ - M,i)}{o\,.\cos(e\,a\,f - 90^\circ)\,.\sin(180^\circ - T,i)}.$$

The ratio of $m : n$ and $m : o$ may be immediately obtained from either of these equations when $v = 1$.

THE RHOMBOID.

The Rhomboid.

Fig. 166 to 122, and 132 to 137.

Crystallographical Elements.

(245.) Inclination of planes at the terminal edge differs in different minerals, and is denoted by P, P'

$$P,P'' = 180^\circ - P,P'.$$

(246.) Plane angle $b\,d\,a$ may be found from the equation

$$\cos \tfrac{1}{2}\,b\,d\,a = \frac{R\,.\cos 60^\circ}{\sin \frac{1}{2}\,P,P''}$$

whence $d\,a\,f = 180^\circ - b\,d\,a$ is known.

Edges equal.

(247.) Inclination of terminal edge to axis may be thus found:

$$\cos e\,d\,n = \frac{\cot 60^\circ\,.\cot \frac{1}{2}\,P,P'}{R}.$$

(248.) Inclination of oblique diagonal to axis may be obtained from the equation

$$\cos e\,d\,n = \frac{R\,.\cos \frac{1}{2}\,P,P'}{\sin 60^\circ},$$

whence $e\,d\,c = e\,d\,n + e\,d\,n$ is known,

and $d\,f\,i = 180^\circ - e\,d\,c.$

(249.) But $e\,d\,c$ may be found directly from the equation

$$\cos e\,d\,c = \frac{R\,.\cos P,P}{\sin \frac{1}{2}\,P,P'}.$$

(250.) Ratio of edge to half oblique diagonal,

$$d\,b : d\,e :: R : \cos \tfrac{1}{2}\,b\,d\,a,$$
$$:: 1 : \frac{\cos 60}{\sin \frac{1}{2}\,P,P'}.$$

(251.) Ratio of edge to half horizontal diagonal,

$$d\,b\,.\,b\,e :: R : \sin \tfrac{1}{2}\,b\,d\,a,$$

$$:: 1 : \frac{\{(\sin \frac{1}{2}\,P,P')^2 - (\cos 60^\circ)^2\}^{\frac{1}{2}}}{\sin \frac{1}{2}\,P,P'},$$

for $(\sin \frac{1}{2}\,b\,d\,a)^2 = R^2 - (\cos \frac{1}{2}\,b\,d\,a)^2$

$$R^2 - \frac{R^2\,(\cos 60^\circ)^2}{(\sin \frac{1}{2}\,P,P')^2}$$
$$= \frac{R^2\,\{(\sin \frac{1}{2}\,P,P')^2 - (\cos 60^\circ)^2\}}{(\sin \frac{1}{2}\,P,P')^2}$$

(252.) Ratio of edge to one-third of axis,

$$d\,b : d\,n :: R : \cos b\,d\,n$$
$$:: 1 : \frac{\cot 60\,.\cot \frac{1}{2}\,P,P'}{R^2}.$$

Axis $= 3\,d\,n$:

for the edges being equal, and the terminal angles equal, the plane $a\,b\,c$ is perpendicular to the axis; therefore $e\,n\,c$ is also perpendicular to it.

Let $f\,o$ be parallel $e\,n$, and because $d\,e = e\,f$, $\therefore d\,n = n\,o$, but $e\,n = f\,o$, whence $o\,i = d\,n$,

and $\quad d\,n + n\,o + o\,i = 3\,d\,n,$

and $\quad e\,n = 2\,e\,n.$

Simple Decrements on the Angles.

(253.) $\overset{v}{\mathrm{A}}$, $\quad v = \dfrac{\sin\frac{1}{2}\,\mathrm{P,P'} \,.\, \sin(\mathrm{P},b - e\,d\,e)}{\cos 60^\circ \,.\, \sin(180^\circ - \mathrm{P},b)}$.

(254.) $\quad = \dfrac{\sin\frac{1}{2}\,\mathrm{P,P'} \,.\, \sin(\mathrm{P},c' - e\,d\,c)}{\cos 60^\circ \,.\, \sin(180^\circ - \mathrm{P},c')}$.

(255.) $\overset{v}{\mathrm{O}}$, $\quad v = \dfrac{\sin\frac{1}{2}\,\mathrm{P,P'} \,.\, \sin(\mathrm{P},e' - d\,f\,i)}{\cos 60^\circ \,.\, \sin(180^\circ - \mathrm{P},e')}$.

And similar expressions in which P,g, or P,i, or P,l are respectively substituted for P,e, will give the laws producing the planes g, i, and l.

(256.) When the Rhomboid is *acute*,

$$\overset{v}{\mathrm{E}}, \quad v = \frac{\sin e'\,d\,a \,.\, \mathrm{R}}{\sin\frac{1}{2}\,a\,d\,b \,.\, \tan(180^\circ - \mathrm{P},h)}.$$

For let a line passing through $i\,a$ be produced to l, and let $d\,l$ be perpendicular to $l\,a$, and $f\,m$, $b\,m$ respectively parallel to $a\,l$, $d\,l$;

$$e'\,b : b\,f :: \sin\tfrac{1}{2}\,a\,d\,b : \mathrm{R},$$
$$b\,m : b\,f :: \cos(90^\circ - e'\,d\,a) : \mathrm{R},$$
$$:: \sin e'\,d\,a : \mathrm{R},$$
$$\therefore e'\,b : b\,m :: \sin\tfrac{1}{2}\,a\,d\,b : \sin e'\,d\,a.$$

(257.) When the Rhomboid is *obtuse*,

$$e'\,b : b\,m :: \sin\tfrac{1}{2}\,a\,d\,b : \cos(e'\,d\,a - 90^\circ),$$

and $$v = \frac{\mathrm{R} \,.\, \cos(e'\,d\,a - 90^\circ)}{\sin\frac{1}{2}\,a\,d\,b \,.\, \tan(180^\circ - \mathrm{P},h)}.$$

It is manifest that the planes replacing the angle at E are similar to those at O but in an inverted position, and that the Laws of Decrement producing any of the planes of *Mod.* e, f, g, h, i, k, l, m, might with equal propriety be referred either to E or O. It will, however, be convenient to refer the planes of *Mod.* h to the angle E, and all the others to the angle O.

Decrements on the Edges.

(258.) The Laws of Decrement on the terminal edges may be found as follows:

$$\overset{v}{\mathrm{B}}, \quad v = \frac{\sin(\mathrm{P},o - \mathrm{P,P''})}{\sin(180^\circ - \mathrm{P},o)}.$$

(259.) Those on the lateral edges may be thus known:

$$\overset{v}{\mathrm{D}}, \quad v = \frac{\sin(\mathrm{P},q - \mathrm{P,P''})}{\sin(180^\circ - \mathrm{P},q)}.$$

Intermediary Decrements.

When these affect the terminal angles, they produce the planes of *Mod.* d. And when they modify the lateral angles, they produce the planes f, k, and m.

The angles of the spherical triangle required to determine the laws of intermediary decrements on the terminal solid angles, are

$$\mathrm{A} = 180^\circ - \mathrm{P},d,$$
$$\mathrm{B} = \mathrm{P,P'},$$
$$\mathrm{C} = 180^\circ - \mathrm{P},d;$$

and those required for the decrements on the lateral solid angles, are

$$\mathrm{A} = 180^\circ - \mathrm{P} \text{ on } f, \text{ or } k, \text{ or } m,$$
$$\mathrm{B} = \mathrm{P,P''},$$
$$\mathrm{C} = 180^\circ - \mathrm{P''} \text{ on } f, \text{ or } k, \text{ or } m.$$

(260.) The indices p, q, r of the planes f are found to be in the following constant ratio to each other:

$$p = q\,r,$$
$$= r + 1,$$
$$r > 1;$$
$$\therefore \text{ if } r = 2,\ q = 3, \text{ and } p = 6.$$

This arises from the condition that the intersection of f and f' is parallel to the axis of the Rhomboid; and the ratio may be easily obtained by considering the planes P, P′, P″ as coordinate planes, and finding the equations of the traces of the plane c and one of the planes f on the plane P″.

From these equations, r being supposed the same in both, the values of p and q are known.

The following formulæ will be found useful in the examination of Crystals belonging to this form.

P,a being given, to find P,P′ and conversely.

(261.) $\quad \cos\frac{1}{2}\,\mathrm{P,P'} = \dfrac{\cos 30^\circ \,.\, \sin \mathrm{P},a}{\mathrm{R}}$

(262.) $\quad \sin \mathrm{P},a = \dfrac{\mathrm{R} \,.\, \cos\frac{1}{2}\,\mathrm{P,P'}}{\cos 30^\circ}$.

n,n′ being given, to find P,P′ and conversely.

(263.) $\quad \cot\frac{1}{2}\,\mathrm{P,P'} = \dfrac{\mathrm{R} \,.\, \cos\frac{1}{2}\,n,n'}{\cos 60^\circ}$.

(264.) $\quad \cos\frac{1}{2}\,n,n' = \dfrac{\cot\frac{1}{2}\,\mathrm{P,P'} \,.\, \cos 60^\circ}{\mathrm{R}}$.

For $e\,d\,n$ is the inclination of the oblique diagonal on the axis of the Rhomboid whose planes are n, n', n'', &c.

$$\cos e\,d\,n = \frac{\mathrm{R} \,.\, \cos\frac{1}{2}\,n,n'}{\sin 60^\circ},$$

and by equating this value of $\cos e\,d\,n$ with that given by (247.), (263.) and (264.) are obtained.

(265.) A series of Rhomboids more obtuse than the primary, of which *Mod.* n may be regarded as the first member, might be produced by the successive truncation of the terminal edges of the derived Rhomboids. And another series more acute than the primary, of which *Mod.* g may be regarded as the first member, might also be produced by planes on the angles of each successive Rhomboid, which should intersect the planes P in parallel lines.

The relations of any member of *either* of these to the primary may be found as follows.

Obtuse Series.

Let P denote the primary Rhomboid,
1, the 1st derived, corresponding to *Mod.* n,
2, the 2d derived,
m, the m^{th} derived,
P,P′, the inclination of the primary planes,
$\mathrm{P,P'}_m$, the corresponding angle of the m^{th} derived Rhomboid.

The line corresponding to $e\,n$ in P, is in $1 = 2\,e\,n$,
$2 = 2^2\,e\,n$,
$m = 2^m\,e\,n$.

Let $e\,d\,n$ of 1 be denoted by $e\,d\,n_1$,
of 2 . . . . $e\,d\,n_2$,
of m . . . . $e\,d\,n_m$;

$$d\,n :: e\,n :: 1 : \tan e\,d\,n,$$
$$d\,n :: 2^m\,e\,n :: 1 : \tan e\,d\,n_m:$$

hence $\tan e\,d\,n = \dfrac{\tan e\,d\,n_m}{2^m}$;

but $\cos e\,d\,n = \dfrac{1}{\{1 + (\tan e\,d\,n)^2\}^{\frac{1}{2}}}$;

hence $(\tan e\,d\,n)^2 = \dfrac{(\sin 60^\circ)^2 - (\cos \frac{1}{2} P,P')^2}{(\cos \frac{1}{2} P,P')^2}$

$= \dfrac{(\sin 60^\circ)^2 - (\cos \frac{1}{2} P,P'_m)^2}{2^{2m}(\cos \frac{1}{2} P,P')^2}.$

(266.) From these two values of $(\tan e\,d\,n)^2$ the following equations are derived:

$$(\cos \tfrac{1}{2} P,P')^2 = \frac{(\cos \frac{1}{2} P,P'_m)^2 . (\sin 60^\circ)^2 . 2^{2m}}{(\sin 60^\circ)^2 + (\cos \frac{1}{2} P,P'_m)^2 . (2^{2m} - 1)}.$$

(267.) $(\cos \frac{1}{2} P,P'_m)^2 =$

$$\frac{(\cos \frac{1}{2} P,P')^2 . (\sin 60^\circ)^2}{2^{2m}\{(\sin 60^\circ)^2 - (\cos \frac{1}{2} P,P')^2\} + (\cos \frac{1}{2} P,P')^2};$$

(268.) $2^{2m} = \dfrac{(\cos\frac{1}{2} P,P')^2\{(\sin 60^\circ)^2 - (\cos\frac{1}{2} P,P'_m)^2\}}{(\cos\frac{1}{2} P,P'_m)^2\{(\sin 60^\circ)^2 - (\cos\frac{1}{2} P,P')^2\}}$

$= a$;

and $m = \dfrac{\log a}{2 \log 2}.$

Acute Series.

Here the 1st derived corresponds to *Mod. g*, and the

$e\,n$ of P is in $1 = 2^{-1}\,c\,n$,

$2 = 2^{-2}\,c\,n$,

$m = 2^{-m}\,c\,n$,

and the preceding formulæ may be applied to this series by substituting 2^{-2m} for 2^{2m}.

Hence, when any two of the quantities P,P', P,P'_m, and m are known, the third may be found.

(269.) The Laws of Decrement which would immediately produce the successive members of the obtuse and acute series from the primary Crystal, may be readily found from the relations of the principal sections of the derived Rhomboids to that of the primary.

Of the obtuse series the symbol of the

1st is	$\overset{\frac{0}{1}}{A}$ or $\overset{1}{B}$	5th is	$\overset{\frac{10}{11}}{A}$
2d is	$\overset{\frac{2}{1}}{A}$	6th is	$\overset{\frac{22}{21}}{A}$
3d is	$\overset{\frac{2}{3}}{A}$		
4th is	$\overset{\frac{6}{5}}{A}$	mth is	$\overset{\frac{2^m+2(-1)^m}{2^m+(-1)^{m-1}}}{A}$

The symbols of the acute series are as follows:

1st is	$\overset{\frac{1}{1}}{O}$	5th is	$\overset{\frac{21}{11}}{O}$
2d is	$\overset{\frac{3}{1}}{O}$	6th is	$\overset{\frac{43}{21}}{O}$
3d is	$\overset{\frac{5}{3}}{O}$		
4th is	$\overset{\frac{11}{5}}{O}$	mth is	$\overset{\frac{2^{m+1}+(-1)^m}{2^m+(-1)^{m+1}}}{O}$

The law of each series is obvious, and the general terms of the mth easily deduced.

Either of the dihedral angles a,b, a,c, a,d, or a,a', (fig. 133,) being given, to find either of the others.

(270.) $\cos \frac{1}{2} a,b = \dfrac{R . \cos \frac{1}{2} a,c}{\tan 60^\circ}.$

(271.) $= \dfrac{\cos 60^\circ . \sin (a,d - 90^\circ)}{R}.$

(272.) $\cos \frac{1}{2} a,c = \dfrac{\sin 60^\circ . \sin (a,d - 90^\circ)}{R}.$

(273.) $= \dfrac{\cos \frac{1}{2} a,b . \tan 60^\circ}{R}.$

(274.) $\sin (a,d - 90^\circ) = \dfrac{R . \cos a,b}{\cos 60^\circ}.$

(275.) $= \dfrac{R . \cos a,c}{\sin 60^\circ}.$

To find the Law of Decrement which gives a regular hexagonal pyramid.

Pyramids of this kind might result from *Mod. d, h, k, m,* or *o.*

(276.) Let fig. 134 represent a section of one of these pyramids perpendicular to the axis, in which $a\,b$, $b\,c$ correspond to two horizontal diagonals of fig. 132.

From the assumed regularity of the pyramid this section must be a regular hexagon. Hence the angle $a\,f\,b = 120^\circ = f\,b\,g = b\,g\,c$.

From the symmetry of the figure the triangles $a\,b\,g$ and $b\,o\,f$ are similar, and $f\,b$ is parallel to $a\,g$. But $a\,g$ bisects $b\,c$, and any planes therefore belonging to a regular hexagonal pyramid must cut the horizontal diagonals $a\,b$, $b\,c$, in the ratio of $2 : 1$.

Whence any planes which shall cut the plane $a\,b\,c$, fig. 135, parallel to the line $a\,n$, will produce these pyramids.

Let $a\,i\,h$ (fig. 135) be a plane of *Mod. d*, intersecting $a\,b\,c$ in $a\,n$.

Let t (fig. 135 and 136) represent the terminal solid angle of the Rhomboid, and let $t\,b : t\,h :: 1 : 2$.

To find $t\,i$, we have in fig. 136,

$$\begin{aligned} t\,h &= 2\,t\,b \\ b\,n &= n\,c \\ k\,b &= b\,c \\ k\,h &= t\,b = t\,c \\ &= t\,a, \text{ fig. } 135; \end{aligned}$$

$\therefore\ k\,h : i\,c :: k\,n : n\,c$

$:: 3 : 1$;

$\left.\begin{aligned} \therefore\ t\,a : t\,i &:: 3 : 2 \\ t\,a : t\,h &:: 3 : 6 \end{aligned}\right\}$ fig. 135.

Hence the indices of this plane would be (6 3 2), and the indices of the plane $a\,h'\,i'$ (fig. 135) would be (6 4 3.)

(277.) We may imagine a series of planes passing through $a\,n$ to lie within two limits. The one the plane $a\,b\,c$, and the other the plane p, (fig. 121.)

The edge $t\,h$ might be supposed to be lengthened until it becomes infinite, when the planes of *Mod: o* would be produced.

The point h may next be conceived to approach towards the axis, while the plane o turning on the line $a\,n$ assumes successively the positions of *Mod. h, f,* and *m*.

In *Mod. f* the edge $t\,h$ becomes parallel to the axis of the Rhomboid, producing a prism with twelve sides.

As the condition of producing a regular hexagonal pyramid is that its planes shall cut the horizontal diagonals in the ratio of $2 : 1$, there might evidently be a

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series of such pyramids belonging to *Mod. d, h, k,* and *m*; but only one can result from *Mod. o*, and one other from *Mod. h*. That from *Mod. o* must be produced by a decrement of two rows, and must have for its symbol $\dot{B}$, and that from *Mod. h* by three rows, and must have for its symbol $\dot{E}$.

For let $d\,o\,g$ (fig. 137) represent one of the planes of *Mod. h*, we have $p\,b : b\,n :: 1 : 2$,

whence $a\,p : p\,b :: a\,d\,(= d\,b) : o\,b$,

$:: 3 : 1$.

Hexagonal Prism.

(278.) It may occasionally be convenient on account of the greater simplicity of the Laws of Decrement, to consider the regular hexagonal prism as an independent primary form, although it is derivable from the Rhomboid by the joint effect of *Mod. a* and *e*, or *a* and *p*.

The Laws of Decrement may then be determined as follows:

Single Planes, a, on the angles.

Let the terminal plane be denoted by P, and the lateral planes by M.

Let each terminal angle be denoted by A, each terminal edge by B, and each lateral edge by G.

Let $B : G :: m : n$,

and the edges of the defect will be as

$$p\,m : 2\,r\,n :: \sin(P,a - 90°) : \sin(180° - P,a).$$

Two Planes, b, on the angles.

The law may be found by the general method before explained.

Single Planes, c, on the terminal edges.

The edges of the defect will be as

$$p\,m\,\frac{\sqrt{3}}{2} : r\,n :: \sin(P,b - 90°) : \sin(180° - P,b).$$

Planes, e, on the lateral edges.

The edges of the defect will be as

$$p : r :: \sin(180° - M,e) : \sin(M,e - 60°).$$

(279.) Having thus shown how the laws of decrement may be determined when the inclination of the secondary plane to the primary is known, it is now proposed to discover that inclination from the known elements of the primary form, and the Law of Decrement.

Let it be required to find the angle at which a plane whose symbol is $\dot{A}$ inclines on a primary plane.

1st. Suppose this plane to occur on the square prism:

$$v = \frac{p}{r} = \frac{n\,R\,\sqrt{2}}{m\,.\tan(180°-P,a)}.$$

$$(280.)\quad \therefore \tan(180° - P,a) = \frac{r\,n\,R\,\sqrt{2}}{p\,m}.$$

2d. If it occurs on the right rhombic prism,

$$v = \frac{p}{r} = \frac{n\,R^2}{m\,.\cos\tfrac{1}{2}M,M'\,.\tan(180° - P,a)}.$$

$$(281.)\quad \therefore \tan(180° - P,a) = \frac{r\,n\,R^2}{p\,m\,.\cos\tfrac{1}{2}M,M'}.$$

3d. If the plane whose inclination to the primary is required, have for its symbol $\dot{H}$, and the primary form be a right rhombic prism,

The Rhomboid.

$$v = \frac{p}{r} = \frac{\sin(180 - M,g)}{\sin(M,g - M,M')};$$

whence it will be found that

$$(282.)\quad \tan M,g = \frac{p\,R\,.\sin M,M'}{p\cos.\,M,M' - r\,R}.$$

And in other cases of simple decrements, the dihedral angles which have been used to determine the laws, may be found by analogous methods when the laws are known.

The inclinations of the primary planes to planes produced by intermediary decrements may also be found from the known laws, and from the plane angles of some of the primary or secondary planes.

(283.) Professor Whewell of Cambridge has, in a Paper inserted in the *Philosophical Transactions* for 1825, given a general form to the problem of finding the inclination or dihedral angle of any two planes from their indices, and of finding the indices from the given angle.

But general and elegant as the solutions given in this Paper are, we are induced to believe that the more direct methods already explained in this Treatise, will, from their greater simplicity, and the comparative ease with which they may be applied, be found in most cases more serviceable to the practical Mineralogist.

In order, however, to place before the reader the most comprehensive and entire view of the mathematical relations of Crystals which has yet been given, we insert the following brief abstract of Mr. Whewell's communication to the Royal Society, referring the reader to the Paper itself for the details of its application to particular cases.

Let a solid angle, denoted in the Tables of Modifications by A of the cube, or square prism, or right rhombic prism, or rhomboid, or O of the oblique rhombic prism, or doubly oblique prism, be regarded as the origin of a system of coordinates, of which the three adjacent edges are the axes.

Let the dihedral angle at the axis $x = \alpha$,

.... $y = \beta$,

.... $z = \gamma$,

and the angle formed by the axis

x and a perpendicular on the plane $y\,z = \delta$,

y .... $x\,z = \epsilon$,

z .... $x\,y = \zeta$.

Then let $\cos\alpha = a$, $\cos\beta = b$, $\cos\gamma = c$,
$\cos\delta = d$, $\cos\epsilon = e$, $\cos\zeta = f$,

and let θ be the dihedral angle of two planes whose equations are

$$\frac{x}{p} + \frac{y}{q} + \frac{z}{r} = 0,^*$$

$$\frac{x}{p'} + \frac{y}{q'} + \frac{z}{r'} = 0.$$

The planes expressed by these equations are supposed to pass through the origin, and they may be expressed generally by the symbols

* Professor Whewell has used the letters *h, k,* and *l* to denote the portions of the edges intercepted by secondary planes, and has adopted *p, q,* and *r* to denote the *reciprocals* of those portions. Having, however, in this Treatise used *p, q,* and *r* to express Mr. Whewell's lines *h, k* and *l*, we have substituted $\frac{1}{p}$, $\frac{1}{q}$, and $\frac{1}{r}$ for *p, q,* and *r* in his equations.

$$(p\ q\ r),\ (p'\ q'\ r');$$

the first index always referring to the axis x, the second to y, and the third to z.

According to the law of symmetry, the solid angle which is assumed as the origin of the system of co-ordinates may in the cube and rhomboid be replaced by six planes, which would require to be denoted by six distinct symbols. And these would be supplied by permuting the three indices, thus, (p, q, r) (p, r, q) (q, r, p) (r, q, p) (r, p, q) (q, p, r), the order of these symbols being that in which the planes they represent occur on the Crystal.

When *all* the indices are to be permuted, they may be written in the symbol of each plane with commas between them, thus, (p, q, r).

And every *particular* symbol in which the three indices are separated by commas, is known to belong to a *general* symbol, in which *all* those indices are subject to permutation.

On the other primary forms there cannot occur more than two planes upon any solid angle, and in this case only two of the indices, as p and q, are to be permuted, and the form of the particular symbol becomes $(p, q; r)$, the semicolon denoting that r is not subject to permutation. The symbol of the two planes would in this case be $(p, q;\ r)$ $(q, p; r)$.

And when, as in the doubly oblique prism, the law of symmetry requires only one plane on each solid angle, the indices are not subject to any permutation; a condition which is expressed by separating them by semicolons, thus, $(p; q; r)$.

Planes which replace any angle of a Crystal may be referred to that which has been assumed as the origin of the coordinates; but in this case the angles made by a transferred plane with the coordinate planes will be the supplements of its inclinations to the primary planes adjacent to it, and one or more of the indices of the transferred plane will be negative, as $(p\ -q\ -r)$ or $(-p\ q\ r)$.

Planes replacing any of the edges may also be referred to the assumed coordinates, but one index will then be 0, and one or both of the others may be positive or negative; and the *general* symbol might be $(p\ 0\ r)$; observing in *particular* symbols to add the commas or semicolons as required by the law of symmetry.

The symbol of the primary plane of the

$$\begin{array}{ll} y\,z \text{ is} & (1, 0, 0) \\ x\,z & (0, 1, 0) \\ x\,y & (0, 0, 1). \end{array}$$

If all the indices of a symbol be multiplied or divided by any quantity, the character of the plane denoted by the altered symbol will not be changed, but its new position will be parallel to that indicated by the original symbol.

The dihedral angle, or the inclination of two planes whose symbols are (p, q, r) (p', q', r') has been denoted by θ, and we may express the angle made by (p, q, r) and (p'', q'', r'') by θ'.

The angle θ may be found from the following equations, observing that in the cube and the rhomboid the primary edges are equal; in the square and right and oblique rhombic prisms the terminal edges are equal, but differing from the lateral ones; and that in the doubly oblique prisms the three edges adjacent to O are unequal.

We shall suppose the planes whose angle is required, to occur on each of the classes of primary forms.

1st. *On the cube and square prism,* where

$$\alpha = \beta = \gamma = 90^\circ,$$
$$\therefore\ a = b = c = 0,$$
$$\text{and } d = e = f;$$

(284.) $-\cos\theta =$

$$\frac{\dfrac{1}{p\,p'} + \dfrac{1}{q\,q'} + \dfrac{1}{r\,r'}}{\left\{\left(\dfrac{1}{p^2} + \dfrac{1}{q^2} + \dfrac{1}{r^2}\right) - \left(\dfrac{1}{p'^2} + \dfrac{1}{q'^2} + \dfrac{1}{r'^2}\right)\right\}^{\frac{1}{2}}}.$$

2d. *On the right rhombic prism,*

$$\begin{array}{ll} \alpha = \beta = 90^\circ, & \therefore a = b = 0, \\ \gamma = \text{M,M}', & \therefore c = \cos \text{M,M}', \\ \delta = \epsilon = \text{M,M}' - 90^\circ, & \therefore d = e = \cos(\text{M,M}' - 90^\circ), \\ \zeta = 0, & \therefore f = \text{R} = 1. \end{array}$$

(285.) $-\cos\theta =$

$$\frac{\dfrac{1}{p\,p'} + \dfrac{1}{q\,q'} + \dfrac{d^2}{r\,r'} - c\left(\dfrac{1}{p'\,q} + \dfrac{1}{p\,q'}\right)}{\left\{\left(\dfrac{1}{p^2} + \dfrac{1}{q^2} + \dfrac{d^2}{r^2} - \dfrac{2\,c}{p\,q}\right)\left(\dfrac{1}{p'^2} + \dfrac{1}{q'^2} + \dfrac{d^2}{r'^2} - \dfrac{2\,c}{p'q'}\right)\right\}^{\frac{1}{2}}}$$

3d. *On the oblique rhombic prism,*

$$\begin{array}{ll} \alpha = \beta = \text{P,M}, & \therefore a = b = \cos \text{P,M}, \\ \gamma = \text{M,M}', & \therefore c = \cos \text{M,M}', \end{array}$$

M,M′ may be $>$ or $<$ 90°.

Let M,M′ be $>$ 90°,

and $\delta = \epsilon$ may be known from the equation

(286.) $$d = e = \frac{-\cos \text{M,M}' . -\cos f\,a\,e}{\text{R}}.$$

(287.) and $$\cos f\,a\,e = \frac{\cot \text{P,M} . \cot \frac{1}{2}\text{M.M}'}{\text{R}},$$

$$\zeta = \text{P},h - 90^\circ,$$
$$\therefore f = \cos(\text{P},h - 90^\circ),$$
$$\text{and } \cos \text{P},h = \frac{\text{R} . \cos \text{P,M}}{\sin \frac{1}{2}\text{M,M}'}.$$

Let M M′ $<$ 90°,

(288.) and $$d = e = \frac{\cos(90^\circ - \text{M,M}') . -\cos f\,a\,e}{\text{R}}.$$

(289.) $-\cos\theta =$

$$\frac{\dfrac{1}{d^2}\left(\dfrac{1}{p\,p'} + \dfrac{1}{q\,q'}\right) + \dfrac{1}{f^2 r\,r'} - \dfrac{c}{d^2}\left(\dfrac{1}{p'\,q} + \dfrac{1}{p\,q'}\right) - \dfrac{a}{d\,f}\left(\dfrac{1}{p'\,r} + \dfrac{1}{p\,r'} + \dfrac{1}{q'\,r} + \dfrac{1}{q\,r'}\right)}{\left\{\left\{\dfrac{1}{d^2}\left(\dfrac{1}{p^2} + \dfrac{1}{q^2}\right) + \dfrac{1}{f^2 r^2} - \dfrac{2\,c}{d^2\,p\,q} - \dfrac{2\,a}{d\,f\,r}\left(\dfrac{1}{p} + \dfrac{1}{q}\right)\right\}\left\{\dfrac{1}{d^2}\left(\dfrac{1}{p'^2} + \dfrac{1}{q'^2}\right) + \dfrac{1}{f^2 r'^2} - \dfrac{2\,c}{d^2\,p'\,q'} - \dfrac{2\,a}{d\,f\,r'}\left(\dfrac{1}{p'} + \dfrac{1}{q'}\right)\right\}\right\}^{\frac{1}{2}}}.$$

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4th. *On the doubly oblique prism,*

$$\alpha = P,M, \quad \therefore\ a = \cos P,M,$$
$$\beta = P,T, \quad b = \cos P,T,$$
$$\gamma = M,T, \quad c = \cos M,T;$$

δ, ϵ, and ζ may be known from the equations

(290.) $$d = \frac{-\cos b\,a\,f. - \cos M,T}{R},$$

(291.) $$e = \frac{-\cos c\,a\,f. - \cos M,T}{R},$$

(292.) $$f = \frac{-\cos c\,a\,f. - \cos P,T}{R}.$$

(293.) $$\sin \tfrac{1}{2}\, b\,a\,f = R\left(\frac{-\cos\frac{1}{2}(P,M + P,T + M,T)\ .\ \cos\frac{1}{2}(P,M + M,T - P,T)}{\sin P,M\ .\ \sin M,T}\right)^{\frac{1}{2}}.$$

(294.) $$\sin \tfrac{1}{2}\, c\,a\,f = R\left(\frac{-\cos\frac{1}{2}(P,M + P,T + M,T)\ .\ \cos\frac{1}{2}(M,T + P,T - P,M)}{\sin M,T\ \sin P,T}\right)^{\frac{1}{2}}$$

(295.) $$-\cos\theta = \frac{\frac{1}{d^2 p p'} + \frac{1}{e^2 q q'} + \frac{1}{f^2 r r'} - \frac{c}{d e}\left(\frac{1}{p' q} + \frac{1}{p q'}\right) - \frac{b}{d f}\left(\frac{1}{p' r} + \frac{1}{p r'}\right) - \frac{a}{e f}\left(\frac{1}{q' r} + \frac{1}{q r'}\right)}{\left\{\left(\frac{1}{d^2 p^2} + \frac{1}{e^2 q^2} + \frac{1}{f^2 r^2} - \frac{c}{2 d e p q} - \frac{b}{2 d f p r} - \frac{a}{2 e f q r}\right) \times \left(\frac{1}{d^2 p'^2} + \frac{1}{e^2 q'^2} + \frac{1}{f^2 r'^2} - \frac{c}{2 d e p' q'} - \frac{b}{2 d f p' r'} - \frac{a}{2 e f q' r'}\right)\right\}^{\frac{1}{2}}}$$

5th. *On the rhomboid,* $\alpha = \beta = \gamma = P,P'$, $\therefore a = b = c = \cos P,P'$; and $\delta = \epsilon = \zeta$.

(296.) $$-\cos\theta = \frac{\frac{1}{p p'} + \frac{1}{q q'} + \frac{1}{r r'} - a\left(\frac{1}{p' q} + \frac{1}{p q'} + \frac{1}{p' r} + \frac{1}{p r'} + \frac{1}{q' r} + \frac{1}{q r'}\right)}{\left\{\left\{\frac{1}{p^2} + \frac{1}{q^2} + \frac{1}{r^2} - 2a\left(\frac{1}{p q} + \frac{1}{p r} + \frac{1}{q r}\right)\right\}\left\{\frac{1}{p'^2} + \frac{1}{q'^2} + \frac{1}{r'^2} - 2a\left(\frac{1}{p' q'} + \frac{1}{p' r'} + \frac{1}{q' r'}\right)\right\}\right\}^{\frac{1}{2}}}$$

On the Parallelisms of the Edges of Crystals.

(297.) The resources of Crystallography in determining the Laws of Decrement by which secondary planes are produced, are not limited to the methods already explained. In certain cases those laws may be inferred from Parallelisms among some of the edges of combination of the different planes. Thus the Parallelism of the terminal edge of the plane d of the square prism to the diagonal of the terminal plane, implies a decrement by one row on the lateral edge of the prism.

This is one of the most simple cases that can occur. Others, however, of a much more complicated nature may be determined from similar considerations.

The following are the principal classes of Parallelisms that occur among the edges of Crystals.

For the sake of generality, the doubly oblique prism, fig. 95, has been used in the diagrams about to be referred to.

(298.) When two adjacent edges are replaced by single planes resulting from any Law of Decrement, and the solid angle between them is also replaced by a single plane produced by the same law, the plane on the angle is a parallelogram, as in fig. 138.

In this figure the plane on the angle intersects the lateral planes parallel to their intersection by the planes on the edges. The indices of both must therefore be similar. And the symbols $\dot{D}$, $\dot{O}$, $\dot{F}$, may be said to express the conditions for rendering the plane on the angle a parallelogram.

When the replaced edges are *similar*, as they are in the regular forms, the plane replacing the angle becomes a rhomb.

(299.) When a plane on the angle is cut in parallel lines by planes on the edges, the decrement *in height* of the three planes being the same, as at a, b, c, d, fig. 139, the decrement *in breadth* of the plane on the angle will be equal to the sum of the decrements *in breadth* of the planes on the edges.

If in this figure the planes on the edges are represented by $\overset{r}{D}$, $\overset{r'}{F}$, it will be found that the condition for rendering the edges of the plane on the angle parallel, is that its symbol should be $\overset{r+r'}{O}$.

(300.) When a plane replacing an edge is intersected in parallel lines by planes replacing the adjacent solid angles, and produced by the same Law of Decrement, as at a, b, c, d, fig. 140 and 141, the planes on the edge and the planes on the angles must intersect two of the primary planes in parallel lines.

In fig. 140 the planes on the angles intercept the lateral planes parallel to their intersection by the plane on the edge. The conditional indices for which may be readily found from what has been before stated. When the angles are *similar*, as in fig. 65, the symbols might be $\ddot{B}$, $\dot{A}$; $\hat{B}$, A_r; or $\overset{y}{B}$, $(B_p\ B'_q\ G_r)$; and they will be analogous to these for the other primary forms.

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Fig. 141 shows that the indices relating to the terminal edges must be the same in the symbols of the three planes.

(301.) When the intersection of planes on two adjacent terminal edges is parallel to the intersection of one of those with a plane on the lateral edge, as in fig. 142, the relation of the plane on the lateral edge to those on the terminal edges will be as follows:

Let the symbol of the plane on the terminal edge adjacent to the lateral truncated edge be $\frac{p}{r}$, and that of the plane truncating the second terminal edge be $\frac{p'}{r}$, the symbol of the plane on the lateral edge will be $\frac{p}{p'}$, for $a\,b$ will then be parallel to $c\,d$, and $a\,c$ to $c\,f$.

(302.) Where an angle is replaced by a single plane which is intersected in parallel lines by two planes on the same angle resulting from the same law, as in fig. 143, the relation of the indices may be found as follows.

The edge $f\,s$ is the intersection of two planes $c\,a\,s$, $m\,k\,s$, on the angle c.

The plane $g\,h\,s$ evidently coincides with the edge $f\,s$, and if it be supposed to move parallel to itself until it reaches the position $n\,o\,p$, it must be intersected in the parallel lines $t\,v$, $u\,x$, by the planes $c\,a\,s$, $m\,k\,s$.

Let $e\,m$ and $e\,c$ represent p molecules.

$e\,a$ and $e\,k$ .... q

$e\,s$.............. r

To determine the law of the plane $g\,h\,s$ we require the ratio of $e\,h$ to $e\,s$. But as $e\,s$ is assumed to represent r molecules, it is only necessary to determine $e\,h$ in terms of p and q.

In fig. 141 let $e\,c = p$, $e\,k = q$,

and we shall have $\qquad e\,h = \dfrac{2\,p\,q}{p+q}$.

For from the nature of the figure

$$m\,d = d\,c$$

$$\text{and } a\,b = b\,k;$$

and by similar triangles we have

$$c\,e : k\,e :: p : q :: d\,c : b\,k,$$
$$:: d\,f : f\,b,$$
$$:: d\,e : b\,e;$$

$$\text{whence } d\,f : d\,f + f\,b\,(= d\,b) :: p : p+q,$$
$$d\,e : d\,e - b\,e\,(= d\,b) :: p : p-q,$$
$$\text{and } d\,e : d\,f :: p+q : p-q;$$
$$\therefore\ d\,e : d\,e - d\,f\,(= f\,e) :: p+q : 2\,q$$
$$:: p : \frac{2\,p\,q}{p+q}$$
$$:: e\,c : e\,h.$$

Hence the index of the planes $g\,h\,s$, or $n\,o\,p$, becomes $\dfrac{2\,p\,q}{r\,(p+q)}$.

The preceding are, however, only particular cases of the following general expression given by Professor Whewell in the Paper already referred to.

Parallelisms of Edges of Crystals.

Let the plane whose indices are $(p_2\,q_2\,r_2)$ truncate the intersection of the planes $(p_1\,q_1\,r_1)$ and $(p_3\,q_3\,r_3)$, and we have

$$(303.)\quad \frac{1}{p_2}\left(\frac{1}{q_1 r_3} - \frac{1}{q_3 r_1}\right) + \frac{1}{q_2}\left(\frac{1}{p_3 r_1} - \frac{1}{p_1 r_3}\right) + \frac{1}{r_2}\left(\frac{1}{p_1 q_3} - \frac{1}{p_3 q_1}\right) = 0.$$

If the planes 1 and 3 are produced by the same law, then $p_1 = q_3$, $q_1 = p_3$, and $r_1 = r_3$; and

$$(304.)\qquad \frac{p_2\,q_2}{(p_2+q_2)\,r_2} = \frac{p_1\,q_1}{(p_1+q_1)\,r_1}.$$

If in this equation $p_2 = q_2$, and $r_2 = r_1$, it becomes

$$(305.)\qquad p_2 = \frac{2\,p_1\,q_1}{(p_1+q_1)},$$

and corresponds to (302.)

If planes 1 and 3 are on the angles, and plane 2 on the edge between them, as in fig. 140, p_1 is negative and $p_2 = \infty$, and

$$(306.)\qquad \frac{q_2}{r_2} = \frac{\dfrac{p_1}{r_1} + \dfrac{p_3}{r_3}}{\dfrac{p_1}{q_1} + \dfrac{p_3}{q_3}}.$$

If, as in (300.), $q_1 = q_3$ and $r_1 = r_3$,

$$(307.)\qquad \frac{q_2}{r_2} = \frac{q_1}{r_1}.$$

If planes 1 and 2 are on adjacent terminal edges, and 3 on a lateral edge, as in fig 142, then $r_1 = r_2$, $q_1 = \infty$, $p_2 = \infty$, $r_3 = \infty$, and the equation corresponds to (301.)

$$(308.)\qquad \frac{p_1}{q_2} = \frac{p_3}{q_3}.$$

If planes 1 and 3 are on adjacent edges, and 2 on the angle between them, then $p_1 = \infty$, and $q_3 = \infty$, and

$$(309.)\qquad \frac{1}{p_2}\cdot\frac{p_3}{r_3} + \frac{1}{q_2}\cdot\frac{q_1}{r_1} - \frac{1}{r_2} = 0.$$

If, as in (299.), $p_2 = q_2$, and $r_1 = r_2 = r_3$, then

$$(310.)\qquad p_2 = p_3 + q_1.$$

If $p_3 = q_1$ and $r_2 = r_1$, then

$$(311.)\qquad \frac{p_2}{r_2} = \frac{2\,q_1}{r_1}.$$

(312.) Mr. Levy has given the following formulæ in a Paper in the VIth volume of the *Edinburgh Philosophical Journal*, p. 227, on the method of finding the law of decrement of any secondary plane, modifying any parallelopiped, whenever two of the edges of that plane, *not being parallel to each other*, are parallel to two edges of the Crystal whose relations to the primary edges are known.

Let p_5, q_5, r_5, be the unknown indices of the new plane, which may be called plane 5. Let p_1, q_1, r_1, and p_2, q_2, r_2, be the known indices of two planes to whose intersection one edge of plane 5 is parallel. And p_3, q_3, r_3, and p_4, q_4, r_4, the known indices of two other planes, to whose intersection another edge of plane 5 is parallel, and

Crystallography.

(313.) $$\frac{p_5}{r_5}=\begin{array}{c}\left(\frac{1}{r_1\,p_2}-\frac{1}{r_2\,p_1}\right)\cdot\left(\frac{1}{q_3\,r_4}-\frac{1}{r_3\,q_4}\right)\\ \hline \left(\frac{1}{r_1\,p_2}-\frac{1}{r_2\,p_1}\right)\cdot\left(\frac{1}{q_3\,p_4}-\frac{1}{p_3\,q_4}\right)\\ +\left(\frac{1}{q_1\,r_2}-\frac{1}{q_2\,r_1}\right)\cdot\left(\frac{1}{p_3\,r_4}-\frac{1}{p_4\,r_3}\right)\\ \hline +\left(\frac{1}{q_1\,p_2}-\frac{1}{q_2\,p_1}\right)\cdot\left(\frac{1}{p_3\,r_4}-\frac{1}{p_4\,r_3}\right)\end{array}$$

(314.) $$\frac{q_5}{r_5}=\begin{array}{c}\left(\frac{1}{r_1\,q_2}-\frac{1}{r_2\,q_1}\right)\cdot\left(\frac{1}{p_3\,r_4}-\frac{1}{r_3\,p_4}\right)\\ \hline \left(\frac{1}{r_1\,q_2}-\frac{1}{r_2\,q_1}\right)\cdot\left(\frac{1}{p_3\,q_4}-\frac{1}{q_3\,p_4}\right)\\ +\left(\frac{1}{p_1\,r_2}-\frac{1}{p_2\,r_1}\right)\cdot\left(\frac{1}{q_3\,r_4}-\frac{1}{q_4\,r_3}\right)\\ \hline +\left(\frac{1}{p_1\,q_2}-\frac{1}{p_2\,q_1}\right)\cdot\left(\frac{1}{q_3\,r_4}-\frac{1}{q_4\,r_3}\right)\end{array}$$

If the instersection of the planes 1 and 2 be parallel to a diagonal of the primary form, the plane 5 will be parallel to the same diagonal; in this case two of the indices will be equal. If $p_1 = q_1$, and $p_2 = q_2$, the values of $\frac{p_5}{r_5}$ and $\frac{q_5}{r_5}$ become equal; and by reducing the above equations, after the necessary substitutions are made, the following will result:

(315.) $$\frac{p_5}{r_5}=\frac{q_5}{r_5}=\frac{\frac{1}{q_3\,p_4-p_3\,q_4}}{\left(\frac{1}{q_3\,r_4}-\frac{1}{r_3\,q_4}\right)+\left(\frac{1}{p_3\,r_4}-\frac{1}{r_3\,p_4}\right)}.$$

If the intersection of the planes 1 and 2 be parallel to an edge of the primary form, the plane 5 will be parallel to the same edge, and one of the indices will be infinite. If r_1 and r_2 become infinite, the values of $\frac{p_5}{r_5}$, $\frac{q_5}{r_5}$, become infinite also. But if equation 1 be divided by 2, the following equation will be obtained, which does not contain the indices of planes 1 and 2, but gives the values of p_5 and q_5 in terms of the indices of planes 3 and 4,

(316.) $$\frac{p_5}{q_5}=\frac{\frac{1}{q_3\,r_4}-\frac{1}{q_4\,r_3}}{\frac{1}{p_3\,r_4}-\frac{1}{p_4\,r_3}}.$$

The facilities afforded by the Parallelisms of Edges in determining the relations of Crystals will be shown by the following examples.

(317.) Fig. 145 is one of the forms of what is termed by Mineralogists muriate of mercury, and it is also the crystalline form of calomel.

The edges of c being rendered parallel by a, both planes must have the same index, and the respective symbols may be $\overset{1}{B}$, and $\overset{1}{A}$.

(318.) Fig. 146 is the form of a Crystal of sulphate of nickel.

In this figure the edges of the plane $a1$ produced by the intersection of c and c' are parallel, and those of c produced by the intersection of $a2$ and $a'2$ are also parallel. Hence the Laws of Decrement producing all these planes are known.

Parallelisms of Edges of Crystals.

For if $\overset{1}{B}$ be the symbol of c, then $\overset{1}{A}$ must be that of $a2$, and $\overset{2}{A}$ that of $a1$.

(319.) Fig. 147 represents a Crystal of scheelate of soda, the primary form of which is a doubly oblique prism.

The planes g and e evidently replace two of the terminal edges, and the plane e is intersected in parallel lines by g and i. If, therefore, we assume the symbol of the plane i to be $\overset{1}{H}$, e and g must be represented by $\overset{1}{B}$ and $\overset{1}{D}$.

(320.) Fig. 148 is a Crystal of oxide of tin, the planes of which may be determined as follows:

Let $c1$ be assumed to result from a decrement by 1 row on the terminal edge of a square prism, and its symbol will be $\overset{1}{B}$.

$a1$ must then be represented by $\overset{1}{A}$, and

$c2$ by $\overset{\frac{1}{2}}{B}$.

$c3$ is known from measurement to result from a decrement by 5 rows in height, and to have for its symbol $\overset{\frac{1}{5}}{B}$.

b may be determined from the following considerations. The edges of the plane $a1$, parallel to its intersection with $c1$, must be parallel to the diagonals of the lateral planes. The planes b therefore which cut M parallel to the intersection of $a1$ and $c1$ must intersect M parallel to a diagonal, and the symbol of the planes b must therefore be of the form A_v. But as $c3$ is cut in parallel lines by b, (300.) b must cut a *terminal* and *lateral* edge in the ratio of one to five, and its symbol must therefore be A_5. It must also cut the terminal edges in the same ratio, and hence as

$c1$ is cut in parallel lines by b, (fig. 141,) the symbol of $c\,1$ must be $\overset{\frac{1}{3}}{G}$.

$a2$ being cut parallel by the planes b, (302.) must have its index of the form $\frac{2\,p\,q}{r\,(p+q)}$. But as it has been found in the symbol representing b that

$$p = 1$$
$$q = 5$$
$$r = 5,$$

the symbol of $a\,2$ becomes $\overset{\frac{1}{3}}{A}$.

d is known to have for its symbol $\overset{1}{G}$, and the symbol of

$e\,2$ may be ascertained, by a construction analogous to fig. 139, to be $\overset{\frac{1}{3}}{G}$.

Hence all the planes of this complicated figure may be determined from the measurement of $c1$ and $c3$.

(321.) Particular cases of Parallelisms will also give the laws of particular planes, as may be seen in a Memoir by Mr. Montiero on the Law of Decrement producing a particular Crystal of carbonate of lime, inserted in No. 201 of the *Journal des Mines* for September, 1813.

Fig. 149 represents the Crystal examined by Mr. Montiero.

The planes m, m', were known by the striæ on their surface parallel to their oblique diagonal to correspond with *Mod. m* of the rhomboid.

The position of the planes m and m', relatively to the edge of the primary form, being thus known, it was readily perceived that the plane e corresponded with *Mod.* c of the same rhomboid, and the planes q with some particular modification belonging to class q.

Let fig. 150 represent the primary rhomboid of carbonate of lime. The plane m' (fig. 149) is known to result from a decrement by one row on the superior edges of that rhomboid. The lines $i\,l$, $l\,m$, would, therefore, represent the intersections of the plane m' with the primary planes, the points l and m being the middle of the edges $d\,f$ and $f\,l$.

From the middle of the edge $d\,s$, draw $h\,b$, $h\,f$, and the triangle $b\,h\,f$ will represent the position on the primary form of the plane e. (Fig. 149.)

The planes m' and e are thus observed to intersect each other at the points c and n, and, consequently, the line $c\,n$ would correspond to their edge of combination.

This edge in fig. 149 is replaced by the plane q, and from the Parallelism of its Edges it must itself be parallel to the edge it replaces.

If, therefore, the line $q\,r$ be drawn parallel to $a\,b$ and passing through the point c, and the line $o\,p$ parallel to $q\,r$ and passing through the point n, we shall, by joining $o\,q$ and $p\,r$, obtain the position on the primary form of the plane q.

And the ratio of $q\,d$ to $d\,o$, will give the Law of Decrement by which the plane q has been produced.

It is evident that $d\,h = f\,m$,

and $o\,h = p\,m$.

But $df : dh :: on : oh$,

and $fm : fl :: pm : pn$,

$\therefore\ df : fl :: on : pn$,

$:: oh : pf$,

$:: 2 : 1$,

$\therefore\ qd : do :: 3 : 1$;

therefore the plane q is produced by a decrement of three rows in breadth on the plane $a\,b\,d\,f$

On the Methods of Drawing the Figures of Crystals.

(322.) The representation of surfaces, or solid bodies, upon a plane, is the object of the art of perspective.

The theory upon which this art has been founded, supposes an imaginary transparent screen to be interposed between the eye of the observer and the object to be represented; and it supposes also that the rays of light which pass from the object to the eye become, as it were, fixed on the screen, so that when the object is removed, its figure or representation still remains. And the rules of perspective teach the methods of delineating the figures of objects upon a plane, so as to resemble the appearance they would present to the eye if the plane on which they are delineated were transparent, and held between the objects and the eye.

A more familiar conception of the nature of a perspective representation may be derived from looking at a building, or along a street, through a piece of glass, and marking lines on the surface of the glass coinciding with those we are observing through it. These lines, if accurately traced, will evidently represent the object to the eye, such as it appeared when seen through the glass.

When the object observed is a street, the upper and lower edges of the fronts of the houses, which are known to be nearly if not accurately parallel, appear to converge at the remote end of the street, forming a series of lines on the screen something like that shown in fig. 151.

And if this mass of houses were a single solid body, and even much reduced in dimensions, it ought still to be represented on a plane surface by converging lines similar to those in the above figure.

But such a representation of Crystals would convey a very indistinct idea of their forms, and particularly those of complicated secondary Crystals.

Another kind of perspective has therefore been used, which supposes parallel lines to be drawn from the several angles of the figure obliquely to a plane parallel to a lateral plane of the cube and square prism, and to a diagonal of the other forms; a method of projection in which all the lines that are parallel in the figure are represented by parallel lines in the drawing. The axis of the rhomboid, and the lateral edges of the other forms being drawn perpendicular to the plane on which the figure is supposed to rest.

(323.) *To draw a cube or square prism.* Fig. 152.

For a cube make $e\,g\,h\,f$ a square, and for a square prism make $e\,o$ or $e\,o'$ to $c\,f$ in the same proportions as they are found in the Crystal to be delineated.

Take $f\,i$ and $k\,i$ such that the figure may appear symmetrical, and draw $k\,v$, and the other lines to complete the figure.

(324.) *To draw a right rhombic prism.* Fig. 153.

On a horizontal line $a\,b$ take $a\,c = d\,b$; and from the points a, b, c, d, raise the four perpendiculars shown in the figure. Take $a\,e = b\,f$ such as to give the figure a convenient form for placing the secondary planes upon it.

Take $d\,g$ to $a\,b$ in the proportion of a *lateral* edge to the *greater* diagonal of the Crystal to be delineated, and complete the figure.

(325.) The oblique rhombic prism may be drawn in a similar manner. But as the angle $e\,d\,f$ may sometimes be acute, the ratio of $a\,b$ to $d\,g$ must be that of the *horizontal* diagonal of the Crystal to a lateral edge; and $a\,c = b\,f$ should be so taken as to present the most correct representation of the true character of the Crystal.

(326.) *To draw a doubly oblique prism.* Fig. 154.

As the lateral edges of this prism are not perpendicular to either of its diagonals, its base cannot rest on a horizontal plane, while its lateral edges are perpendicular.

On the line $a\,b$, the perpendiculars at a, c, d, and b, may be raised, and the distances $a\,c = d\,b$, and $a\,e$ and $f\,b$ may be taken so as best to represent the character of the given Crystal, the ratio of $e\,a$ to $f\,b$ and of $c\,g$ to $a\,b$ being deduced from its measured angles.

(327.) *To draw a rhomboid.*

Let $a\,b$ (fig. 155) represent the axis trisected by the parallel lines $e\,g$, $h\,k$.

From a draw $a\,g$ at such an angle with $a\,b$, and through the point f in the axis draw $e\,g$ at such an angle with the axis, as to place the figure in a convenient position for exhibiting the secondary planes.

The ratio of the axis $a\,b$ to the horizontal diagonal $c\,d$ of the rhomboid to be delineated is supposed to be known.

On the line $e\,g$ take $f\,g = 2\,f\,e$, and through e and parallel to $n\,o$ draw $e\,c = e\,d$, such that $c\,d : a\,b$ as the horizontal diagonal to the axis.

Draw $c\,e$, $d\,m$, and $h\,b$, equal and parallel to $a\,g$, and then the remaining lines to complete the figure.

(328.) The delineation of the secondary forms of Crystals may be effected either by truncating the figures of the primary forms, or by circumscribing those forms with the planes of the secondary Crystal.

When the secondary form, whether it be simple or compound, is to be exhibited in its entire state, with all the primary planes effaced, the best method will be to delineate a small primary form, and to envelope that with the secondary planes; but when parts of the primary planes are also to be shown in the figure of the secondary Crystal, a larger primary form may be drawn, and then be cut down, as in the Tables of Modifications.

The fidelity of the representation of any secondary form, will depend upon the accuracy with which the intersections of the secondary planes with the primary and with each other are drawn.

From the preceding explanations relative to secondary planes, it is obvious that such planes may be correctly placed on a primary form by drawing them so that they shall cut the primary edges in the proportions denoted by the Laws of Decrement which produce them. And the line at which two planes so drawn intersect each other, corresponds to their common edge on the Crystal.

If the planes *b* of the right rhombic prism (fig. 74) be supposed to correspond to the symbol, $(B_2\, B'_1\, H_3)$, those proportions of the corresponding edges must be taken for the plane *b*, and for *b'*, $(B_1\, B'_2\, H_3)$, and the line at which these planes would cut each other, would represent the edge between *b* and *b'*.

But it will be inconvenient when there are many secondary planes to be drawn, to find the intersections in this manner. And we must then resort to the following general method.

(329.) Let it be required to draw a right rhombic prism modified by planes corresponding to the symbols

$$\overset{2}{B},\ \overset{2}{E},\ \overset{1}{G},\ A_{\frac{1}{3}},\ (B_2\, B'_1\, H_3)$$

$$e,\quad c,\quad h,\quad b,\qquad\qquad b_2.$$

Let the primary forms (fig. 156 and 157) be drawn in pencil, of equal dimensions; with their terminal and lateral edges respectively parallel, on fig. 157 draw *u o* parallel to the short diagonal of the terminal plane, and from the points *u* and *o* draw *u o v p*, parallel to the lateral edges. The plane *h* would evidently be represented by *u v o p*. Let the line *a a'* be drawn on the plane *h*, and through the diagonals *q r*, *s t*.

The plane *c* which should next be drawn must obviously lie between *h* and P. The Law of Decrement from which this plane is supposed to result, is two rows in breadth.

If, therefore, two of the primary terminal edges of fig. 156 are extended to *c* and *c'*, so that $q\,c = 2\,q\,q''$ and $q\,c' = 2\,q\,q'$, the plane *a c c'* will represent the plane *c*, and the line *c c'* will touch the primary form at the solid angle *d*. The line *d a*, which bisects *c c'* at *d*, may be called the *directing line*, for placing the plane *c* between *h* and P, by taking some point *d* in the diagonal *q r*, (fig. 157,) and drawing *d a* parallel to *d a*. (Fig. 156.) The lines *g h'*, *i k* being drawn through *d* and *a* parallel to *u v*, the plane *g h' i k* will represent the required plane *c*. By drawing lines parallel to *g h'* and *i k*, at corresponding distances from the diagonals *q r*, *s t*, and from the points *q*, *r*, *s*, and *t*, the figure with the planes *h* and *c* upon it may be completed, and may be traced separately in pencil, as in fig. 158, preparatory to the addition of the planes *e*.

Methods of Drawing the Figures of Crystals.

To produce these planes, first draw *k x* on fig. 158, and for the intersection of the planes *c* and *e* draw *k l* parallel to *a c*, (fig. 156,) and from the point *l* draw *l y* parallel to *k x*.

Having thus produced the planes *d*, *c*, and *e*, we may add the planes b_1 and b_2, by tracing fig. 158 on a separate paper, as in fig. 160, and drawing parallel to it an entire primary form, as shown by fig. 159.

The directing planes $b\, b'''\, b_1$, and $b'\, b''\, b_1$ on fig. 159, represent the two planes b_1, b'_1, (fig. 160,) and $b\, b'''\, b_2$, $b'\, b''\, b_2$, (fig. 159,) represents b_2, or 2 in fig. 160; and $n\, z\, b'''\, z'$ (fig. 159) is evidently parallel to plane *e*, fig. 160.

The intersection of $b\, b'''\, b_1$, with $n\, z\, b'''\, z'$, is the line $n\, b'''$; its intersection with P is $b\, b'''$; with M, it is $b\, b_1$; and with $b'\, b''\, b_1$ it is $b_1 m$.

If, therefore, from the point 1 (fig. 160) we draw the line 1 6, parallel to $n\, b'''$; 6 5, to $b\, b'''$; and 1 3, to $b\, b_1$, we shall obtain three of the edges of plane b_1. From the point 5, (fig. 160,) draw the intersection of b_1 and b'_1 parallel to $m\, b_1$, (fig. 159,) and by drawing on fig. 160, 3 4, parallel to $b\, b_2$, and the intersection of 2 and 2', (fig. 160,) parallel to $m\, b_2$, (fig. 159,) we shall delineate the planes b_1 and 2; observing that those planes intersect each other in a line parallel to the intersection of b_1 and P. The positions of b'_1 and 2 may be obtained by a similar method of proceeding, and the other corresponding planes may be drawn by a similar process, or by parallel lines, or by finding the relation of their edges, or angles, to some known points on the Crystal.

By means analogous to these, the most complicated figures may be accurately produced.

(330.) But it very frequently happens that the Law of Decrement will suggest some relation between the position of the secondary edges or angles and some known points or lines of the primary form, which will supersede the necessity of any directing diagram. The figure of the rhombic dodecahedron affords an example of this nature.

The easiest method of drawing this figure is to project the cube, as shown in fig. 161, and through its centre, and perpendicular to its planes, to draw the lines *a b*, *c d*, *e f*.

Those lines are parallel respectively to the edges of the cube. Take on each line, and in each direction from the point in the centre of the cube, where the lines intersect each other, a quantity equal to that edge of the cube to which the particular line is parallel, and draw lines from the extremities of those portions of the lines to the solid angles of the cube.

Many expedients will probably occur to those who are accustomed to draw Crystals, which will greatly abridge the laborious processes just described. These will, however, form particular cases, and will depend on the degree of attention and ingenuity employed in framing the diagrams.

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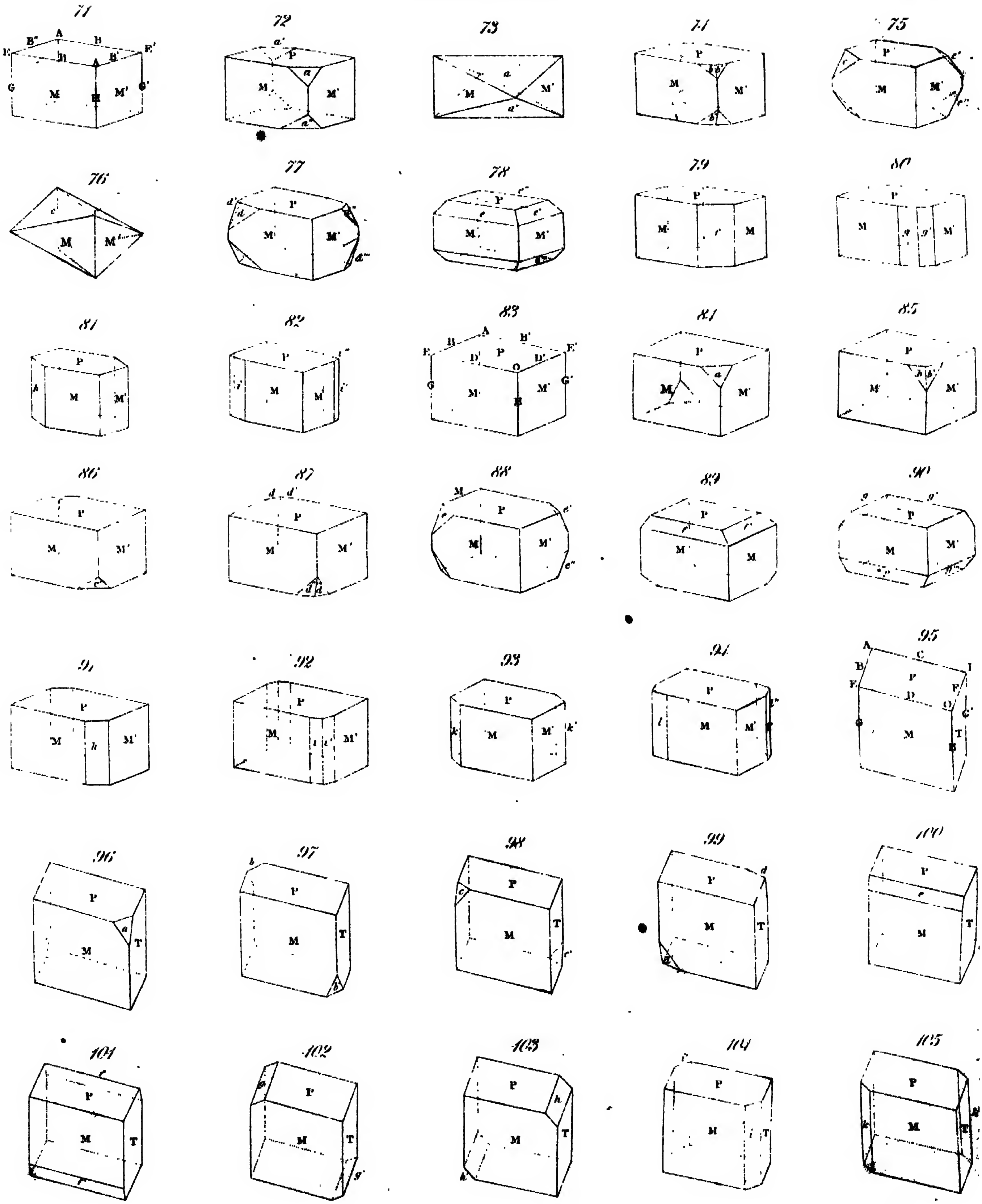
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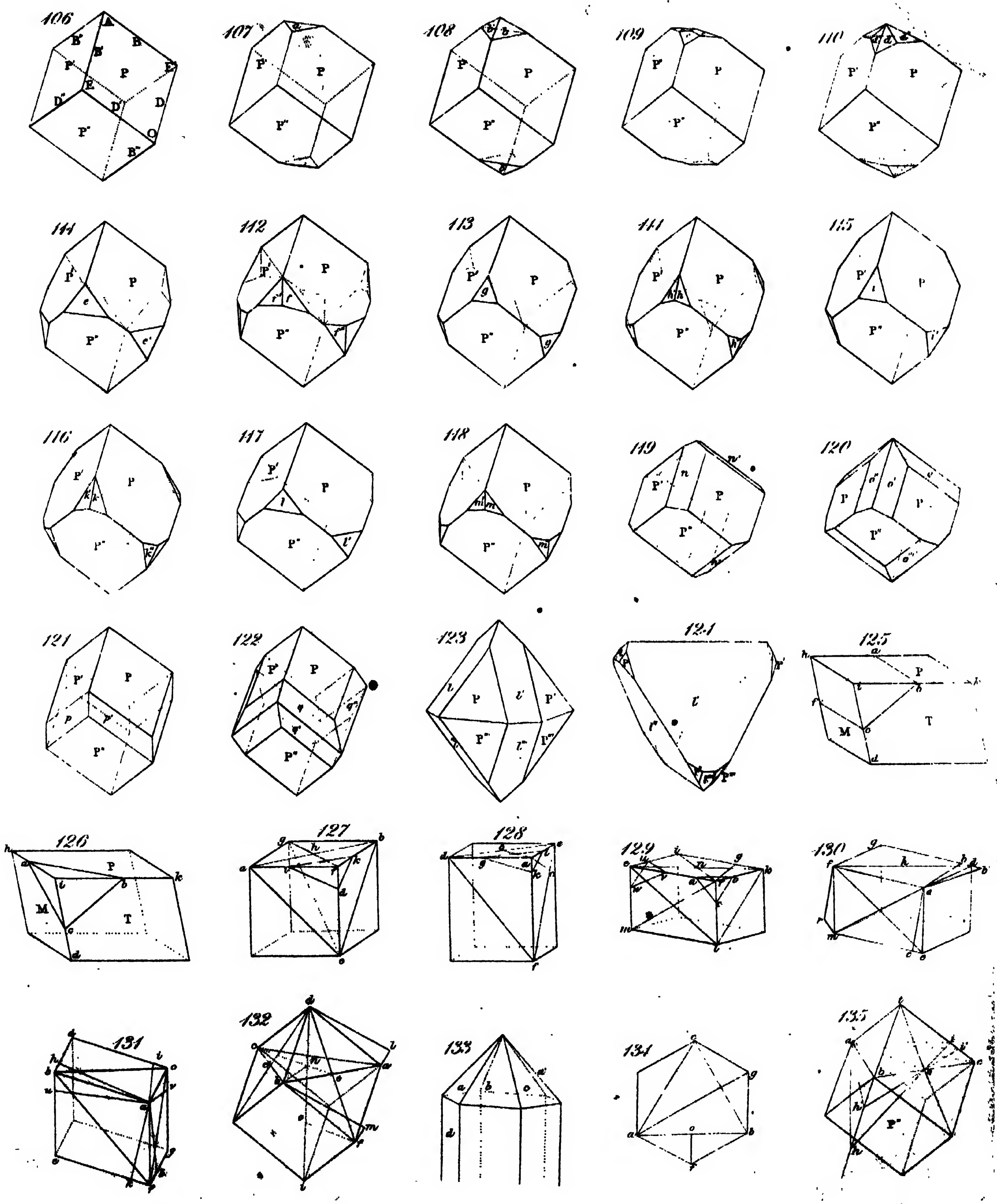
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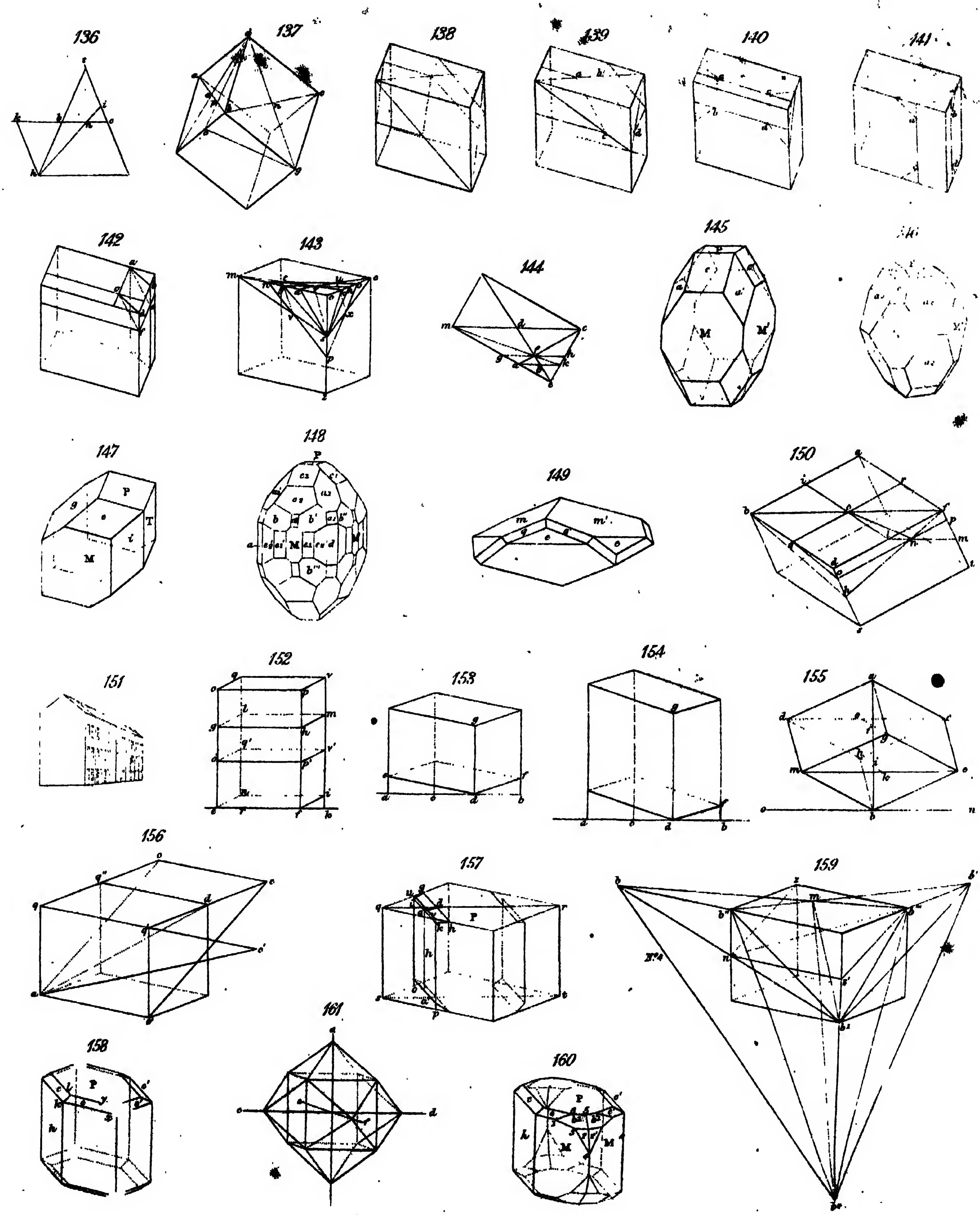
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Introductory Observations.

(1.) **Mineralogy** is defined by Kirwan to be *the Art of distinguishing Mineral substances from each other.*

All bodies found in or upon the earth, not being vegetable or animal, are termed Minerals.

(2.) It has been stated in the Introduction to Crystallography, that we are indebted to Haüy for the first satisfactory explanation of the mutual relations of crystalline forms; and it is also due to his memory to add, that his views of Mineralogy were more precise and philosophical than those of any author by whom he had been preceded. In recommending this pursuit to the favourable notice of others, he observes, that if the motives by which we are led to the cultivation of any branch of Natural Science, were founded solely upon the pleasure afforded by a casual inspection of the productions to which it relates, Zoology and Botany would claim our first regard; but that if we overcome this first unfavourable impression, and look a little more closely to only a few individuals belonging to the Mineral kingdom, we shall, he says, find them possessed of a regularity of structure, an almost infinite variety of distinct, yet related forms, and many other properties, not only capable of affording a high degree of interest, but offering inducements to the collector of Minerals to enter upon a wider range of philosophical inquiry.

The necessity of exact Mineralogical knowledge to the Geologist has been very justly and forcibly expressed by Mr. Aikin in the introduction to his *Manual of Mineralogy*, published in 1815. He says: "The absolute necessity of extreme accuracy in discriminating one species of Mineral from another is too obvious to require any further remark, if examples were not perpetually presenting themselves of persons very slenderly provided with these rudiments of the Science, who yet undertake geological investigations, and with a peremptoriness, generally in proportion to their ignorance, challenge the credit of new discoveries, or call in question the observations of their predecessors. "It is, indeed, very true that geological speculations are as fascinating to the student as the discrimination of species is generally repulsive; yet it ought to be borne in mind that as all sound scholarship is founded upon Grammar, so all sound Geology depends primarily on a familiar acquaintance with the distinctive characters of simple Minerals."

Of Mineral Species.

(3.) If we examine specimens of the various kinds of Minerals, they will be found to differ considerably in form and colour: some will be opaque, others more or less transparent; and among those which are transparent, some may be observed to produce a double image of the objects seen through them. If the specimens are taken in the hand, some will be found much heavier than others of the same apparent size. If an attempt be made to scratch them with a pin or needle, some will be readily marked by the pin, others will require the steel point to produce the same effect; and others will not be scratched by either. Some may be cut with a knife into thin slices, while an attempt to cut others will produce only powder or fragments, and many will entirely resist the action of the knife. Some may be hammered into thin plates, while others will only be bruised to powder, or broken into angular fragments with plain or curved surfaces.

(4.) If the different specimens were to be analyzed by the Chemist, many of them would agree, and many differ in their composition, apparently denoting identity or difference *of kind* among the Minerals examined; and it might be expected that such Minerals would also be distinguished by corresponding resemblances or disagreements in their external and other characters. But it would occasionally be perceived that specimens which agreed in their chemical composition, exhibited differences in some of their external characters; and that others which agreed in their external characters, differed in their chemical composition. There would, however, *generally* be found among the external or physical characters some which so constantly accompany particular chemical kinds, as to warrant the conclusion that such characters are essential to such *kinds*: but it must be admitted that, until the relations between the chemical and other properties shall be more correctly ascertained, the separation of all the known Minerals into *kinds* or *species*, must, in many instances, be regarded as provisional only, and subject to alterations as their properties become better understood.

(5.) It appears from chemical analysis that *carbonate of lime* which occurs generally in *rhomboids*, as in the common calcareous spar, occurs also in *rhombic prisms*, as in arragonite; and hence it follows that the same elements are subject to different modes of crystalline arrangement. It is apparent that carbonate of lime and arragonite might, from the similarity of their composition, be regarded as belonging to the same *natural* species; while the differences in their form and in their physical properties, which are also *natural* characters, would require them to be considered as distinct *natural* species; but as the practical purpose for which Minerals are divided into species, that of affording the means of distinguishing them from each other, is more completely answered by regarding them as different species, they have been so considered by previous writers on Mineralogy. This property of crystallizing under two distinct forms has been termed *dimorphism;* and in order to preserve a consistent Mineralogical rule, *all* dimorphous substances ought to form two species; and even sulphur, although a *simple* chemical body, as it crystallizes under two separate forms, ought not, perhaps, to become an exception to the rule. Hence it is obvious that there might be two distinct *natural* systems of classification of Minerals, distinguished as the *Chemical* and *Mineralogical;* and if all the discrepancies between Chemical and Mineralogical species were analogous to those of carbonate of lime and arragonite, there would be little difficulty in classing and arranging the whole according to either of these methods. But there are other anomalies

in the relations of the composition and form of Minerals, arising out of what has been termed the *isomorphism* of their molecules, which tend still further to embarrass the distinction of species among several well-known substances. On this subject, however, we must refer our readers to some papers in the Xth volume of the *Phil. Mag.* and *Annals of Philosophy*, and to the *Reports of the British Association for the Advancement of Science.*

(6.) In addition to the uncertainties already noticed in the determination of Mineral species, some further difficulty may occasionally be experienced from the changes which are found to have taken place in the substance of Minerals, without any alteration of external form or cleavage. A Mineral so altered has been termed *epigene* by Haüy; and examples of such changes may be observed in iron pyrites, where the sulphur has left the iron, and oxygen has taken its place; and in carbonate of iron, where the carbonic acid has quitted the Mineral, and left it in the state of an oxide. In both these instances the crystalline forms of the pyrites and carbonate of iron are retained.

(7.) The substance of one Mineral is also occasionally found to have been destroyed or removed, and to have been replaced by that of another, which yet retains the form of the original substance, a change to which the term *pseudomorphism* has been applied. It is not unfrequent among Minerals, but its causes are involved in great obscurity.

(8.) It has also been supposed that Minerals may *pass* from one species into another. As where two distinct species are so mixed, that neither should appear to predominate or envelope the particles of the other, and to assume its proper form and other characters. But the only difficulty that could present itself in this case would arise, not from the compound exhibiting a *false* character, but from its being destitute of *any* precise specific character.

Of Classification.

(9.) Let us suppose that the physical and chemical characters of all the varieties of known Minerals have been ascertained and accurately recorded. The next proceeding of the owner of such a collection would probably be an attempt to arrange these descriptions, so as to exhibit the *natural* relations of the different kinds to each other. In attempting to effect which object, he would immediately perceive that there might be as many different systems of *natural* classification as there are distinct natural characters among Minerals. And hence his first difficulty would be the selection of the particular characters which might afford the best foundation of his *natural* arrangement; but for reasons which we have not space here to discuss, he would probably adopt the chemical composition as his basis.

(10.) Let us now imagine the supposed collection to have been destroyed, and the possessor of it to be desirous of again forming a similar one, with no other assistance than the descriptions that have been preserved of the lost specimens.

As these recorded descriptions are supposed to have been either noted down promiscuously, or to have been afterwards arranged according to composition, it is obvious that however correctly they may have been recorded, they would afford little assistance in identifying new specimens; for the time and labour that would be required for successively comparing each new specimen with each individual description of those which had been destroyed, would render the attempt impracticable.

In order, therefore, to facilitate the recognition of species from recorded descriptions, and thus to practise the *Art of Mineralogy*, it would be found necessary to classify and arrange the several characters with a view to this particular object, and thus to produce what may be termed an *artificial* arrangement.

Mineralogy may therefore be regarded both as a Science and an Art. As a Science in reference to the knowledge requisite for supplying accurate descriptions of Minerals, and forming what may be termed a *natural* classification; and an Art in reference to the arrangement of the descriptive characters for the purpose of afterwards distinguishing Minerals from each other.

(11.) Before we proceed to explain the methods which have been adapted to these purposes, we shall follow Berzelius in a hasty review of the History of Mineralogy, and the methods of classification adopted by preceding authors.

Little is to be discovered in the writings of the Ancients relative to Mineralogy in the modern sense of that term. On the contrary, the earliest histories and descriptions of Minerals are interspersed with fabulous accounts, such as Pliny has recorded of the diamond; which he says is so hard that no blow of the hammer will break it, but that when struck upon an anvil, it will rather split both the anvil and the hammer than suffer itself to be broken, unless it be previously steeped in the blood of a goat recently killed.

The first attempts at a methodical arrangement of Minerals, and the first use of the term *Mineral Kingdom* must be referred to the XVIIth Century, within which period many different systems, or Mineralogical methods, have been published. Some founded on external and physical characters only; others uniting the chemical character to these; and some later ones being strictly chemical.

Wallerius, one of the most distinguished of the early writers, arranged his *species* of Minerals by some of their external and physical characters; such as texture, fracture, figure of the fragments, colour, transparence, hardness, as evinced by giving sparks with steel, effervescence with acids, &c. The systems of Brunner and of Cronstedt were also founded on external characters, and consisted of four principal subdivisions:

Earths,	Bitumens,
Salts,	Metals.

And each of these classes was subdivided into the following orders, dependent on texture or structure.

1. Earthy,	5. Fibrous,
2. Scaly,	6. Granular foliated,
3. Foliated,	7. Compact.
4. Radiated,	

The salts being further determined by their flavour; as

Astringent,	Sweet,
Acid,	Salt, &c.

These systems, it may be observed, were founded at a period when Chemistry had made comparatively little progress; but as that Science improved, we find it resorted to by Mineralogists for supplying other distinguishing characters.

The systems of Werner and of Haussmann were founded upon the chemical and external characters conjointly; and that of Werner was for a considerable period almost exclusively adopted by Mineralogists. It was not, however, published by the author himself, and

coming only through the hands of his pupils, may possibly not have always represented his views with accuracy.

The following is an outline of his method of classification:

Class 1. Earthy Minerals.
Class 2. Saline Minerals.
Class 3. Inflammables.
Class 4. Metals.

In this system the advantages which might result to the Science from any single *natural* method, are unavailable to the student. For the chemical arrangement is continually violated to preserve an apparent consistency in that founded on external characters, which, in its turn, is not unfrequently disturbed by the regard paid to chemical constitution. And hence its followers have seldom agreed concerning the proper place which new Minerals ought to occupy in that system. The system of Haussmann was also founded upon a chemical basis, but more perfect than that of Werner, and was also combined with the consideration of external characters. And hence the disadvantage of attempting to combine conflicting and incompatible systems, was as apparent in this as it had been in the system of Werner.

The principal systems founded on a more strictly chemical basis were first those of Karsten and of Haüy, and, at a later period, of Brongniart, Cleveland, and Phillips; that of Karsten may be said to present the dawn of an attempt at accurate *natural* classification, which has been greatly improved in the hands of Haüy, and has derived still greater advantages from the labours of Berzelius. We shall, therefore, enter no further into the system of Karsten than to say, that its leading divisions are into

1. Earths, 2. Salts,

containing all the soluble varieties arranged according to their acids,

3. Combustibles, 4. Metals.

(12.) The system of Haüy was first published in 1801, and a second edition in 1822.

His definition of a Mineral species is, that all the individuals belonging to it *shall be similar in their composition*, and that their *crystalline forms shall also be similar*. It is obvious from what has preceded that this definition cannot be universally applied. If, he says, we collect crystals of quartz from different parts of the World, we shall observe such a general resemblance among them as would lead to a conclusion of their being similar Minerals. If we examine them chemically, we are supported in this conclusion; and if we measure their angles, we shall find such an agreement among the corresponding ones of different crystals as to leave no doubt that they all belong to one species. Let us now, he says, take a rolled pebble whose lustre, when broken, resembles the fractured parts of crystals of quartz. We analyze the substance, and find it nearly pure silex; we place it in a position in which we may observe the light reflected from its fractured surface, and we perceive that from some parts of that surface not only the rays of light, but the images of objects, are distinctly reflected; we consider those parts as portions of cleavage planes, we detach and measure some fragments, and we discover angles corresponding with some of those presented by the regular crystals of quartz; we therefore include our specimen under the species quartz. We proceed with another specimen of what is termed white cornelian, whose structure is fibrous, whose fragments afford but dull reflections of light, and not any images of surrounding objects. This differs so much in character from the preceding specimens, that at first view we should exclude it from the species. But on analysis, we find that its composition is very nearly similar to that of rock crystals; and as an analogy has been observed to subsist between the crystallized and fibrous structure of other Minerals, we place our white cornelian as a variety of the species quartz.

The following is an outline of the classification adopted by Haüy:

Class 1. Free acids.
Class 2. Metals appearing under another character. (Heteropsides.) These are the earthy Minerals.
Appendix to class 2. The characteristic principle depending upon the silex not yet determined, and being free or combined.
Class 3. Metals appearing as such. (Autopsides.)
Order 1. Not immediately oxidable, unless at a very high temperature, and immediately reducible.
Order 2. Oxidable, and reducible immediately.
Order 3. Oxidable, but not immediately reducible.
a. Sensibly ductile.
b. Not ductile.
Class 4. Combustibles, not metallic.
An appendix to this class, consisting of substances of vegetable origin.
Appendix to the four preceding Classes.
22 substances.

This classification appears equally objectionable with those preceding it, exhibiting as it does a mixture of chemical and physical characters in the same system.

We pass over the systems of Brongniart, Cleveland, Phillips, Breithaupt, Beudant, and other authors who have intervened between the first publication of Haüy's method and the present time, not as unworthy of more particular notice, but because they may be regarded as varieties of the chemical method, modified in a greater or less degree by the introduction of some other principle.

We are indebted to Berzelius for the first attempt at a strictly chemical classification of Minerals. According to this author's system, all chemical compounds are supposed to consist of electro-positive and electro-negative particles, attracted and held together by a force analogous to that by which bodies in different states of electricity are influenced. When Minerals are analyzed, therefore, and their simple constituent parts ascertained, we are, according to this theory, to regard those of the electro-positive and electro-negative elements which present themselves in *such definite proportions as are consistent with the atomic theory, to be essential elementary parts of the Mineral examined*; and upon this principle a general determination of Mineral species has been attempted, and a systematic classification founded.

But this author has candidly acknowledged the difficulties which, in the present state of Chemical Science, attend the inquiry into what are really the essential constituents of Minerals. The first is that of ascertaining correctly, by means of analysis, the nature of all the different kinds of particles which enter into the composition of a compound Mineral, and the still greater difficulty of determining the exact proportions of each kind. This, however, may possibly be overcome by further improvements in practical Chemistry. But the second, and as

it appears to us the insurmountable impediment to the establishment of an accurate chemical determination of Mineral species, arises from the extraneous matter which is so frequently, we might almost say universally, found accompanying the *essential constituents* of the Mineral.

The substance known by the name of Fountainbleau sandstone affords a striking instance of this kind of composition. This Mineral may be regarded either as granular quartz cemented by carbonate of lime, or as carbonate of lime enveloping grains of quartz, yet no one has ever regarded this mixture as constituting a new chemical species. Instances also occur in which only part of a specimen is coloured by foreign matter, which, if it had pervaded the whole specimen, the Chemist would be deceived by analysis, and would erect an accidental variety of some known Mineral into a new species.

On looking over the number of species which Berzelius has formed out of the garnet tribes, it is much to be suspected that accidental mixtures have been reckoned among the essential constituents of several of the varieties examined; a suspicion which may be reasonably entertained from the manner in which the chemical formulæ of Minerals is made up. For we can scarcely imagine a compound, however heterogeneous, whose constituent particles may not be so parcelled out as to appear nearly definitely proportional to each other. It is, however, very possible that some of the Minerals hitherto called garnets, on account of their crystalline form, may really be different substances. But the number of Mineral species which may fairly be regarded as doubtful on account of some supposed heterogeneous mixture of elements will probably be continually reduced by new and more correct analyses; with a due regard to the matrix, to the accompanying substances, and to the purity of the specimens analyzed, as far as that can be judged of from their transparency and other characters.

The order established by the *electro-chemical* relation of bodies is supposed to be generally preserved in all their combinations. Thus if A be *electro-negative* in respect of B and of C, B will generally be electro-negative in relation to C; but this appears not to be universally so; and sometimes one electro-negative body is found combined with two or more bases, and sometimes two acids are combined with a single base.

If, says Berzelius, with these theoretic notions in our mind we look through the productions of the Mineral kingdom, the apparently confused combinations which Minerals present will be immediately pervaded by regularity and order. We perceive an extensive class of Minerals into which silex enters as a constituent, assuming the character of salts, either simple, double, triple, or quadruple, and with various excesses of the *acid* or the *base*. In the same manner we perceive the oxides of titanium, of tellurium, and of other metals, performing the functions of acids, and thus reducing the whole series of Minerals to one uniform system of classification; and the doctrine of definite proportions introduced within a few years into Chemistry, might, if we could fully avail ourselves of its aid, be said to confer on this system of Mineralogical classification a degree of almost mathematical precision. But, as we have already stated, in consequence of the difficulty of ascertaining the proportions of the actual ingredients of Minerals, and the still greater difficulty of distinguishing those which are essential to the species analyzed, we are not yet enabled to confer on a chemical classification all the advantages offered by the improved doctrines of Chemistry.

In the large class of Minerals containing silex, and which are the only ones that are likely to occasion much difficulty, we are persuaded that there are not at present sufficient data to determine their chemical species with accuracy. And in this opinion we have the concurrence of the author himself; for he allows in his *Nouveau Système Minéralogique*, at p. 22, that although the number of analyses already made by Klaproth, and others since his time, supply a large store of materials for the determination of species, yet the entire accomplishment of this object must be the result of future labours, directed sedulously and entirely to the accuracy of analysis. And in p. 92 of the same Work he says, "I cannot be certain that the analysis of the triple or quadruple silicates, or consequently the formulæ deduced from these, are correct. I give them only as examples of the *probable composition* of these Minerals. The art of analysis not being yet advanced to that degree of perfection, which will command our reliance on its results when the ingredients of the substance analyzed are numerous." It is on these grounds that we have omitted the Mineralogical formulæ of Berzelius in this Treatise.

We have, however, adopted provisionally his chemical classification, as it appears in the *Annals of Philosophy, New Series*, vol. xi. p. 422, being, we believe, the best natural arrangement yet proposed. To the list there given, the later examined Minerals have been added.

In this arrangement we have numbered the species, and in the alphabetical list we have given references to these numbers, by which the chemical order of the different species in that list may be readily ascertained.

We have also for the more convenient reference to cabinets which may be arranged according to this system, retained the different substances in the order there adopted by Berzelius, although in his recent Work on Chemistry that order has been a little varied.

Chemical Classification of Minerals.

Iron, native, meteoric. *Aerolite*, 1.
terrestrial, 1. from France, 2.
... 2. from North America, Connecticut, 3.
... 3. Pennsylvania, 4.
volcanic, 5.
native steel? terrestrial, 6.
volcanic, 7.
Copper, native, 8.
Bismuth, native, 9.
Lead, native, 10.
Silver, native, 11.
Mercury, native, 12.
Hydrarguret of silver. *Amalgam*, 13.
Palladium, native, 14.
Platina, native, 15.
Osmium.
Osmiuret of *iridium*, 16.
Gold, native, 17.
Aururet of silver. *Electrum*, 18
Tellurium, native, 19.
Telluret of bismuth, 20.
... ... and silver, 21.
... lead and silver. *Foliated?* 22.
... .. and gold. *Yellow*, 23.
... silver and gold. *Graphic*, 24.
Antimony, native, 25.
Stibiuret of silver. *Antimonial silver*, 26.

Arsenic, native, 27.
Arseniuret of nickel. *Copper-nickel*, 28.
... cobalt. *White cobalt*, 29.
hard, 30.
radiated, 31.
rhombic, 32.
... ... bismuth, iron, &c. *cobalto-bismuthic arsenic*, 33.
... bismuth, 34.
... copper, 35.
... silver. *Arsenical silver?* 36.
... antimony from *Allemont?* 37.
... . *Przbram*, 38.
... manganese, 39.
Carbon, native. *Diamond*, 40.
Anthracite, 41.
Carburet of iron. *Graphite*, 42.
Siderographite? 43.
Azote, native, gaseous, 44.
Selenium, native, 45.
Seleniuret of bismuth and tellurium, 46.
... lead, 47.
... ... and cobalt, 48.
... . copper, 49.
cupriferous seleniuret of lead, 50.
... . mercury, 51.
... .. copper and silver, 52.
... copper, 53.
... ... and silver. *Eukairite*, 54.
... zinc, with sulphur and mercury.
... ... *Riolite*, 55.
... ... *Culebrite*, 56.
Iodine. Iodide of silver, 57.
Chlorine, 58.
Chloride of sodium, 59.
... ammonium, 60.
... calcium, 61.
... magnesium, 62.
... lead, 63.
chloro-oxide. *Berzelite*, 64.
chloro-carbonate, 65.
... copper, 66.
... silver, 67.
... mercury, 68.
Sulphur, native, 69.
Sulphuret of manganese, 70.
... zinc. *Blende*, 71.
... iron. *Pyrites, yellow*, 72.
... *white*, 73.
... *magnetic*, 74.
... cobalt, 75.
... nickel. *Capillary nickel*, 76.
... copper. *Vitreous copper*, 77.
... copper and iron. *Grey*, 78.
Tennantite, 79.
Purple, 80.
Yellow, 81.
Kupferindig, 82.
... lead. *Galena*, 83.
... bismuth, 84.
... ... and copper, 85.
... ... copper, and lead. *Needle ore*, 86.
... tin and copper. *Tin pyrites*, 87.
... silver, 88.
... ... and copper, 89.
... ... copper, lead, and bismuth, 90.
Sulphuret of silver and iron? *Sternbergite*, 91.
... mercury. *Cinnabar*, 92.
... antimony. *Grey antimony*, 93.
Black antimony? 94.
... ... nickel and arsenic, 95.
... ... and nickel. *Hartmannite*, 96.
... ... lead and copper. *Bournonite*, 97.
... ... and copper, 98.
... ... and lead. *Zinkenite*, 99.
... ... lead and silver, 100.
... . and iron. *Jamesonite*, 101.
... ... and iron. *Berthierite*, 102.
... ... and silver. *Romelite*, 103.
... ... and silver. *Red silver*, 104.
Miargyrite, 105.
Polybasite, 106.
... molybdenum, 107.
... arsenic, *red*. *Realgar*, 108.
... ... *yellow*. *Orpiment*, 109.
... selenium, 110.
Sulpho-arseniuret of iron. *Mispickel*, 111.
Huttenbergite, 112.
... cobalt. *Grey cobalt*, crystallized, 113.
.... amorphous, 114.
... nickel, grey nickel, 115.
Oxygen, native, gaseous, 116.
a. Electro-positive oxides.
Oxide of calcium. *Native lime*, 117.
... manganese. *Manganite*, 118.
Varvicite, 119.
Pyrolusite, 120.
Psilomelane, 121.
Hausmannite, 122.
Braunite, 123.
... zinc, *red*, 124.
... iron. *Oligiste*, 125.
Magnetic, 126.
... ... zinc, and manganese. *Franklinite*, 127.
... ... and manganese. *Umber*, 128.
... cobalt and manganese. *Earthy cobalt*, 129.
... nickel, 130.
... copper. *Red copper*, 131.
... ... iron, and manganese. *Black copper*, 132.
... ... and manganese. *Cupreous manganese*, 133.
... lead, yellow. *Massicot*, 134.
... ... red. *Minium*, 135.
... ... and iron. *Beudantite*, 136.
... bismuth. *Bismuth ochre*, 137.
... uranium. *Pitchblende*, 138.
... tin. *Tinstone*, 139.
b. Electro-negative oxides.
Water, 140.
Hydrate of magnesia, 141.
... manganese, 142.
... iron, 143.
... uranium, 144.
Alumina, native. *Corundum*, 145.
Rotten stone, 146.
Aluminate of magnesia. *Spinelle*, 147.
... magnesia and iron. *Pleonaste*, 148.
... iron? *Skorian*, 149.
... zinc. *Automolite*, 150.
... lead. *Plomb-gomme*, 151.
... water. *Gibbsite*, 152.
... ... and iron. *Diaspore*, 153.

Silica, quartz, 154. *Varieties.*
Hydrous quartz. *Opal*, &c. 155.
Hydrosilicite, 156.
Konilite, 157.
Tripoli, 158.
Geyserite, 159.

a. Silicates with a single base.

Silicate of lime. *From Ædelfors*, 160.
Wollastonite, 161.
Okenite, 162
... magnesia. *Serpentine*, 163.
Steatite, 164.
Ecume de mer, 165.
Pyrallolite, 166.
Marmolite, 167.
... zinc. *Electric calamine*, 168.
... manganese, 169.
... cerium, *red.* *Cerite*, 170.
yellow, 171.
... iron. *Hisingerite*, 172.
Chlorophæite, 173.
Chloropal, 174.
Sideroschisolite, 175.
Thraulite, 176.
Nontronite, 177.
... copper. *Dioptase*, 178.
Chrysocolla, 179
... zirconia. *Zircon*, 180.
... alumina. *Kyanite*, 181.
Sillimanite, 182.
Bucholzite, 183.
Fibrolite, 184.
Andalusite, 185.
Chiastolite, 186.

Hydrous silicates of alumina.
Pholerite, 187.
Allophane, 188.
Lenzinite, 189.
Halloysite, 190.
Severite, 191.
Fuller's earth, 192.
Cimolite, 193.
Agalmatolite, 194.
Lithomarge, 195.
Bole, 196.
Mountain soap, 197.
Lemnian earth, 198.
Kollyrite, 199.
Scarbröite, 200.
Kaolin, 201.
Clay, 202.
Ampelite, 203.

b. Silicates with several bases.

1. An alkali, alumina, water.
Apophyllite, 204.
Chabasie, with base of *soda*, 205.
lime. *Levyne*, 206.
Mesotype, 207.
Mesolite, 208.
Mesole, 209.
Analcime, 210.
Gmelinite, 211.
Thomsonite, 212.
Stilbite, 213.
Epistilbite, 214
Heulandite, 215
Brewsterite, 216.
Laumonite, 217.
Skolezite, 218.
Zeagonite, 219.
Harmotome, 220.
Edingtonite, 221.
Prehnite, 222.
Killinite, 223.
Radiolite, 224.

2. An alkali, lime, and water.
Pektolite, 225.

3. An alkali, alumina, anhydrous.
Felspar, 226.
Cleavelandite, 227.
Anorthite, 228.
Petalite, 229.
Spodumene, with *lithia*, 230.
with *soda*, 231.
Gabbronite, 232.
Leucite, 233.
Labradorite, 234.
Scapolite, 235.
Meionite, 236.
Ekebergite, 237.
Elaolite, 238.
Nepheline, 239.
Sodalite, 240.
Ittnerite, 241.
Anhydrous skolezite, 242.
Erlanite, 243.
Glaucolite, 244.

Appendix.
Pearlstone, 245.
Pitchstone, 246.
Pumice, 247.
Sphærulite, 248.
Obsidian, 249.
Lava, 250.

4. An alkali, magnesia, or oxide of iron, or of manganese.
Picrolite, 251.
Picrosmine, 252.
Pinelite, 253.
Talc, 254.
Pyrophyllite, 255.
Chlorite, 256.
Green earth, 257.
Mica, *rhomboidal*, 258.
oblique prisms, 259.
Lepidolite, 260.
Margarite, 261.
Rubellan, 262.
Oderit, 263.
Gieseckite, 264.
Fahlunite, 265.
Pinite, 266.

5. An alkali, oxide of iron.
Achmite, 267.

6. Lime, magnesia, or oxide of iron, or manganese. The silica sometimes replaced by alumina.
Pyroxene, 268.
white, 269.
green, 270.
Manganesian, 271.
Augite, 272.
Jeffersonite, 273.
Bustamite, 274.
Amphibole, 275.

Grammatite, 276.
Actynolite, 277.
Hornblende, 278.
Arfwedsonite? 279.

7. Lime, magnesia, oxide of iron, oxide of manganese.
Ilvaite, 280.
Cronstedtite, 281.
Pyrosmalite, 282.
Peridot, 283.
Hyalosiderite, 284.
Hypersthene, 285.
Bronzite, 286.
Schiller spar, 287.
Knebelite, 288.

8. Lime or magnesia, or oxide of iron or manganese or cerium, alumina.
Epidote, 289.
Zoizite, 290.
Idocrase, 291.
magnesian. *Loboite*, 292.
cupriferous. *Cyprine*, 293.
Garnet, 294.
Grosular, 295.
Aplome, 296.
Almandine, 297.
Magnesian, 298.
Manganesian, 299.
Pyrope, 300.
Essonite, 301
Helvin, 302.
Gehlenite, 303.
Anthophyllite, 304.
Dichroite, 305.
Jade, 306.
Nephrite, 307.
Saussurite, 308.
Sordawalite, 309.
Isopyre, 310.
Tachylite? 311.
Karpholite, 312.
Sapphirin, 313.
Chamoisite, 314.
Indianite, 315.
Latrobite, 316.
Leelite, 317.
Ligurite, 318.
Cerine 319
Allanite, 320.

9. Oxide of iron, alumina.
Staurotide, 321.

10. Glucina, alumina.
Emerald, 322.
Euclase, 323.
Chrysoberil, 324.

11. Yttria, oxide of iron, oxide of cerium, &c.
Gadolinite, from Ytterby, 325.
Kararfoet, 326.
Orthite, 327.
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(14.) It will readily be discovered by the reader, on looking through the preceding chemical classification, that if he desires to ascertain whether a particular Mineral which he sees for the first time is included in it, the order in which the species are there placed, even supposing them accompanied by their descriptions, does not enable him to do so. Some other arrangement, therefore, which for the sake of distinction we have termed artificial, is required for this purpose.

The first attempt at an arrangement of Minerals, with a view of affording the means of recognising them, is, we believe, contained in Aikin's *Manual of Mineralogy*, and is founded on the effects produced by the blowpipe, combined with some other characters. But serviceable as this arrangement might be, it is probable from the infrequency with which the blowpipe is used by Mineralogists, that it has not afforded the assistance it is capable of rendering.

(15.) The only other attempt at an artificial arrangement of Minerals, founded on their external and physical characters, for the purposes of identifying and distinguishing them, which has been published in this Country, is the system of Mohs; that of Weiss, by which it is said to have been preceded, not having to our knowledge been printed either here or in France. The system established by Mohs, although imperfect in respect to a particular class of crystalline forms, and defective in respect to the arrangement of many of the species, which are thrown into appendices to the several *orders* of the system, is said to have fulfilled in a very great degree the object for which it was framed, and to have enabled his pupils to determine Mineral species when first presented to them with a considerable degree of precision. The translation which has appeared in this Country, although made by a pupil of Mohs, eminently acquainted with his subject, and writing our language with great correctness, is yet not given in so perfect an English dress as to enable the reader at all times to comprehend fully the meaning of the author. The difficulty, however, which the reader might experience from this cause, is nothing in comparison with that which he has to encounter in the minute analysis of the principles of the system, its learned yet repulsive nomenclature, and the symbols which represent the crystalline forms. Indeed, so formidable have these characters of the Work appeared to Mineralogists in this Country, that we believe it has had very few, if any readers. We, however, give the following abstract of the system, stripped of its repulsive appendages.

System of Mohs.

Class 1. Sp.gr. under 3.8.
No bituminous odour.
Order 1. Sp.gr. 0.0001, 0.0014.
Gaseous.
Not acid.
2. Sp.gr. 1.0.
Liquid.
No odour or taste.
3. Sp.gr. 0.0015, 3.7.
Acid.
4. Sp.gr. 1.2, 2.9.
Solid.
Soluble in water.
Not acid.
Class 2. Sp.gr. above 1.8.
Tasteless.
Order 1. Non-metallic.
Streak uncoloured.
Hard. 1.5, 5.0.
Sp.gr. 2.2, 3.3.
a. Square or rhombic prisms; Hard. 4.0 or less; cleavage imperfect, oblique.
b. Cube; Hard. 4.0.
c. Single cleavage, bright; sp.gr. 2.4 or less.
d. Hard. under 2.5; sp.gr. 2.4 or less.
e. Hard. under 2.5; sp.gr. 2.4 or less; lustre not resinous.
2. Non-metallic.
Streak uncoloured, or orange yellow
Hard. 2.5, 5.0.
Sp.gr. 3.3, 7.3.
a. Single cleavage; sp.gr. 4.0 or less, 5.0 and more.
b. Lustre adamantine or imperfect metallic; sp.gr. 5.0 and more.
c. Streak orange-yellow; sp.gr. 6.0 and more.
d. Hard. 5.0; sp gr. under 4.5.
e. Hard. 5.0; sp.gr. under 4.0; triple cleavage.
3. Non-metallic.
Streak uncoloured.
Cleavage not single, imperfect.
Hard. 1.0, 2.0.
Sp.gr. above 5.5.
4. Non-metallic.
Colour blue, green, brown.
Cleavage not single.
Hard. 2.0, 5.0.
Sp.gr. 2.0, 4.6.
a. Colour or streak brown; Hard. 3.0 or less; sp.gr. above 2.5.
b. Streak blue; Hard. 4.0 or less.
c. Streak uncoloured; Hard. under 3.0; sp gr. 2.2 or less.
5. Cleavage single, bright.
Hard. 1.0, 4.5.
Sp.gr. 1.8, 3.2.
a. Metallic; sp.gr. under 2.2.
b. Non-metallic; sp.gr. above 2.2.
c. Rhomboid; Hard. 3.0 and more.
d. Metallic; sp.gr. under 2.5.
6. Non-metallic.
Streak uncoloured, brown, blue.
Hard. 3.5, 7.0.

Class 2. *continued.*
Order 6. *continued.*
Sp.gr. 2.0, 3.7.
a. Cube; sp.gr. 3.0 or less.
b. Rhomboid; Hard. 6.0; sp.gr. 2.2 or less.
c. Single cleavage, bright; Hard. 4.0 or less.
d. Lustre pearly; Hard. above 6.0; sp.gr. under 2.5, or above 2.8.
e. Lustre not adamantine; oblique rhombic, or doubly oblique prisms; Hard. 6.0; sp.gr. above 3.3.
f. Traces of form and cleavage; sp.gr. 2 4 or less.
7. Non-metallic.
No metallic adamantine lustre.
Streak uncoloured.
Hard. 5.5, 10.0.
Sp gr. 1.9, 4.7.
a. Hard. 6.0, or less.
Cube; sp.gr. 3.0 and more.
No form or cleavage; sp gr. 2.4 or less
b. No pearly lustre, on cleavage planes; sp.gr. under 3.8.
8. No green streak.
Hard. 2.5, 7.0.
Sp.gr. 3.4, 7.4.
a. Metallic; colour black.
b. Non-metallic; lustre adamantine or imperfect metallic.
c. Streak yellow or red; Hard. 3.5 and more; sp.gr. 4.8 and more.
d. Streak brown or black; Hard. 5.0 and more; or single cleavage.
e. Streak yellow, red, or black; Hard. 4.5 or less.
f. Streak uncoloured; Hard. 6.5 and more; sp.gr. 6.5 and more.
9. Metallic.
Colour not black.
Hard. 0.0, 5.0.
Sp.gr. 5.7, 20.0.
a. Malleable; colour grey; sp.gr. 7.4 and more.
b. Malleable; Hard. above 4.0.
10. Metallic.
Hard. 3.0, 6.5.
Sp gr. 4.1, 7.7.
a. Hard. 4.5 or less; sp.gr. under 5.3.
b. Colour yellow or red; sp.gr. 5.3 or less.
11. Metallic.
Colour grey, black.
Hard. 1.0, 4.0.
Sp.gr. 4.2, 7.6.
a. Colour lead-grey; single cleavage; sp.gr. under 5.0.
b. Colour lead-grey; sp gr. above 7.4.
12. Streak green, brown, red, uncoloured.
Hard. 1.0, 4.0
Sp.gr. 3.9, 8.2.
a. Metallic; colour black.
b. Non-metallic; lustre adamantine.
c. Streak green; colour black.
d. Streak brown, uncoloured; cube; sp.gr 4.0, 4.2.
e. Streak red; Hard. 2.5 or less.
f. Streak red; sp.gr. 4.3 and more.

Class 2. *continued.*

Order 13. Non-metallic.
Colour yellow, red, brown.
Rhombic prism.
Hard. 1.0, 2.5.
Sp.gr. 1.9, 3.6.
a. Single cleavage; sp.gr. 3.4 and more.
b. Streak yellow, red; sp.gr. above 2.1.

Class 3. Sp.gr. under 1.8.
a. Fluid; bituminous odour.
b. Solid; tasteless.

Order 1. Hard. 0.0, 2.5.
Sp.gr. 0.7, 1 6.
a. Streak uncoloured. sp.gr. 1.2 and more.

2. Streak brown, black.
Hard. 1.0, 2.5.
Sp. gr. 1 2, 1.5.

We recommend the reader, if he wishes to ascertain the real value of this arrangement, to attempt a classification of the Minerals he is acquainted with by the characters here given, and to compare his result with the order in which the several Minerals are placed in the translation we have referred to.

(16.) The very brief descriptions given in the following list are all that the space allotted to this Essay will allow, and we must refer the reader to Leonhard's *Handbuch der Oryctognosie*, for the results of Chemical analysis; to Haüy's *Traité de Minéralogie*, and to Phillips's *Elementary Introduction*, for figures and measurements of Crystals; and to the "observations" in Haidinger's translation of the system of Mohs, for much valuable Mineralogical information.

The alphabetical form we have given to our list, will be found convenient for reference. Although, however, the leading form of our list is alphabetical, it is also, with the exception of the compound silicates, chemically arranged according to the *bases*, by which order the ores of each metal are kept together. The reader has thus the two chemical classifications before him. That already given from Berzelius being arranged according to the *acids* with a particular view to the theory of isomorphism.

We have deemed it advisable to give single names to some of the species that before had only their chemical designation, as *Calcite* to Carbonate of lime. These names have generally been derived from places or persons, having observed that significant names derived from some property or character or theoretical view of the substances to which they have been applied, have frequently led to the mistakes of one substance for another, merely because the property from which the significant name was derived, happened to be common to both.

We observe, in looking at the late editions of Beudant's *Mineralogy* and Breithaupt's *Carakteristik*, that these authors also have felt the advantage of denoting Minerals by single names; but they have carried their alterations very much further than appears to be necessary, and they have too frequently followed the exceptionable examples before them, of employing a significant nomenclature.

We have deemed it sufficient to refer specially to the Works of Haüy, Phillips, Haidinger, and Leonhard, as the reader will find in these ample references to other authorities. But we have occasionally found it necessary to quote from other books.

The abbreviations used are the following.

Haüy. *Traité de Minéralogie*, second edition, 1822.

Phil. *Elementary Introduction to Mineralogy*, by W. Phillips, 1823.

Haid. *Treatise on Mineralogy*, by F. Mohs, translated by W. Haidinger, 1824.

Leon. *Handbuch der Oryctognosie*, by K. C. v. Leonhard, 1826.

B.M. *British Mineralogy*. by J. Sowerby.

N.J. Nicholson's *Journal*, 8vo.

P.M. *Philosophical Magazine.*

S.J. Silliman's *Journal.*

An. *Annals of Philosophy.*

An. N.S. *Annals of Philosophy, New Series.*

P.M. and An. *Philosophical Magazine and Annals.*

P.M. and J.S. *Philosophical Magazine and Journal of Science.*

E.P.J. *Edinburgh Philosophical Journal.*

E.P.J. N.S *Edinburgh Philosophical Journal, New Series.*

E.J.S. *Edinburgh Journal of Science.*

E.J.S. N.S. *Edinburgh Journal of Science, New Series.*

Q J.S. *Quarterly Journal of Science.*

Lucas. *Tableau des Espèces Minérales*, 1813.

Gal. *Recueil Minéralogiques par le* Prince Dimitri de Gallizin.

The Mineralogical student will find much useful matter in the Treatises on Mineralogy by Kirwan, Jameson, Aikin, Cleaveland, and those of later writers in France and Germany.

We have followed Mohs in the numbers which express the degree of hardness (Hard.) of Minerals, his scale being as follows.

1. Green talc.	6. Adularia.
2. Gypsum. Rock salt.	7. Quartz.
3. Carbonate of lime.	8. Topaz.
4. Fluorspar.	9. Corundum.
5. Apatite.	10. Diamond.

But we are persuaded that this character requires to be much more accurately ascertained than it has hitherto been, and by a more strict method of comparison than merely passing a knife or file over the substance, and estimating its hardness by the degree of resistance it appears to offer.

Alphabetical List of Minerals.

ACHMITE. *Euchysiderite.* No. 267.
Haid. 3.67. Leon. 513.
Has the form, cleavage, and measurement of Pyroxene. Hard. 6.0, 6.5. Sp.gr. 3.24. Nearly opaque. Lustre vitreous. Colour brownish-black. Streak yellowish-grey.
Found at Eger in Norway.

ALUMINA.

Fluate of Alumina.

a. FLUELLITE. No. 513.
Sowerby, *Brit. Min.* 3.83. 1807. An. 8.242. Haid. 3. 101. Leon. 739.
Occurs in attached octahedral crystals.
Primary form, a Right rhombic prism. CRYST. fig. 71. M,M′=105°. Transparent Colour white.
Found at Stenna Gwyn, Cornwall.

Hydrate of Alumina.

a. DIASPORE. No. 153.
Haüy, 2.163. Phil. 78. Haid. 3.92. Leon. 228.
Occurs in amorphous masses, with a thin columnar structure, the crystals crossing in every direction.

Mineralogy

Primary form, according to Phillips, a Doubly oblique prism CRYST fig 95. P,M = 108° 30′. P,T = 101° 20′. M,T = 64° 54′. Sp.gr. 3.43. Slightly translucent. Lustre vitreous. Colour slightly greenish-grey, and yellowish-brown.

Locality unknown, but supposed to have come from the Uralian mountains.

b. GIBBSITE. No. 152.

Phil. 79. Haid. 3. 103. Leon. 740.

Occurs in irregular stalactitical and tuberculated masses. Structure fibrous, radiating. Hard. 3.0, 3 5. Sp gr. 2.4. Slightly translucent. Nearly dull. Colour greenish or greyish-white. Streak white.

Found at Richmond, Massachusetts, North America.

c. CALAITE *Agaphite. Johnite.* *Mineral Turquoise.* No. 500.

Haüy, 4.516. Phil. 79. Haid. 3.83. Leon. 135.

Occurs in reniform nodules and amorphous masses, and in thin veins. Structure compact. Fracture conchoidal. Hard. 6.0. Sp gr. 2.8, 3.2. Opaque. Colour sky-blue and bluish-green Streak white.

Found in alluvial clay and in trap rock in Khorasan in Persia.

Mellate of Alumina.

a. MELLITE. *Honey stone.* No. 590.

Haüy, 4.445. Phil. 374. Haid 3.56. Leon. 790.

Occurs in attached and imbedded crystals, and small imbedded nodules or grains.

Primary form a Square prism. CRYST. fig. 65. Cleavage very indistinct parallel to the planes *a*, fig 66. Fracture conchoidal. Hard. 2.0, 2 5. Sp.gr. 1.597. Transparent, translucent. Lustre vitreo-resinous. Colour honey-yellow, sometimes reddish or brownish. Streak white.

Found attached to and imbedded in bituminous wood, principally at Artern in Thuringia.

Native Alumina.

a. CORUNDUM.

The blue transparent varieties are the Sapphire; the red, oriental Ruby; the purple, oriental Amethyst; the yellow, oriental Topaz; the opaque, adamantine spar; the granular, Emery. No. 145.

Haüy, 2. 70. Phil. 71. Haid. 2. 199. Leon. 535. 538.

Occurs in imbedded crystals and massive.

Primary form a Rhomboid. CRYST. fig. 106. P,P′= 86° 4′. Cleavage parallel to P, and perpendicular to the axis. Fracture uneven. Hard. 9 0. Sp.gr. 3.91, 3.98. Transparent, translucent, opaque. Lustre vitreous. Colour white, grey, blue, green, yellow, red, brown. Streak white.

Massive varieties, amorphous. Structure perfectly crystalline, or granular and compact with a splintery fracture.

Found in India, China, North America, in Europe chiefly at St. Gothard and in Piedmont.

Alumina, with silica and carbon.

a. ROTTEN STONE. No. 146.

Phil. 50.

Occurs massive. Fracture uneven. Soft, fine earthy, soils the fingers. Opaque. Dull. Colour greyish, reddish, and blackish-brown. Fetid when rubbed or scraped.

Found near Bakewell in Derbyshire, and at Albany near New York.

Phosphate of Alumina.

a. WAVELLITE. *Lasionite.* No. 497

Haüy, 2.161. Phil. 146. Haid. 3.169. Leon. 133.

Mineralogy

Occurs in globular concretions, formed of slender crystals radiating from the centre of the globules, with imperfect terminations, producing a drusy surface. Primary form of the crystals a Right rhombic prism. CRYST. fig. 71. M,M′= 122° 15′. Cleavage parallel to the lateral planes, and the greater diagonal of the prism. Hard. 3.5, 4.0. Sp gr. 2.3, 2 7. Translucent. Lustre vitreous, sometimes pearly on the cleavage planes. Colour nearly white, grey, brown, yellow, green, of various shades.

Found near Barnstaple, in Devonshire; very rarely near St. Anstle, Cornwall; in Ireland, Germany, and Brazil.

Phosphate of Alumina and Ammonia.

a. MAURITCITE. No. 498.

An. de Ch 21.188. Leon. 783.

A white earthy substance from the Isle of France, differing from the preceding Phosphate in the proportions of its constituent parts.

Silicate of Alumina.

a. KYANITE *Cyanite. Disthene. Rhætizite.* No. 181.

Haüy, 2. 357. Phil. 81. Haid. 2. 213. Leon. 406.

Occurs in columnar imbedded crystals and massive.

Primary form a Doubly oblique prism, P,M = 93° 15′. P,T = 100° 50′. M,T = 106° 15′. Cleavage parallel to T very distinct; less so parallel to M; parallel to P indistinct. Fracture uneven. Hard. 5.0 on plane T, 7.0 on the edges and solid angles. Sp.gr. 3.6, 3 675. Transparent, translucent. Lustre vitreous, pearly on T. Colour white, bluish-grey, blue, pale bluish-green, yellow. Streak white.

Massive varieties. Aggregation of crystals promiscuously intersecting each other, sometimes very long, and occasionally so short and small as to appear large granular.

Found at St. Gothard in large crystals, in Scotland, and many other parts of Europe, and in North and South America.

b. SILLIMANITE, No. 182.

Haid. 3.153. Leon. 409

Occurs in imbedded columnar rhombic prisms, of about 106° 30′. Haid.

Cleavage parallel to the long diagonal. Fracture splintery. Hard. 8.0, 8.5. Sp.gr. 3.41. Nearly opaque. Lustre on the cleavage plane nearly adamantine. Colour dark brownish-grey.

Found at Saybrook, Connecticut, North America. It approaches very nearly to Kyanite in its form and composition.

c. BUCHOLZITE, No 183.

Phil. 109. Leon. 409.

A fibrous substance from the Tyrol analyzed by Brandes. It is described as amorphous. Cross fracture imperfectly conchoidal. Hard. about 6 0. Slightly translucent. Lustre resinous. Colour yellowish and greyish-white.

One or two other fibrous Minerals apparently different from this have passed under this name. The composition of the substance analyzed by Brandes is nearly the same as that of Kyanite, and it may have been a fibrous variety of that Mineral.

d. FIBROLITE, No. 184.

Phil. 80. Haid. 399. Leon.

Occurs in small fibrous masses. Hard. 7.5. Sp.gr. 3.214. Translucent, colour greyish-white.

Found in India and China accompanying Corundum.

Fibrous varieties of Epidote, Kyanite, and other substances have passed under this name, and the composition of Bournon's Fibrolite is very nearly the same as that of Kyanite.

e. ANDALUSITE, No. 185.
Haüy, 4.486. Phil. 108. Haid. 2.293. Leon. 404.
Primary form a Right rhombic prism. M,M′ = 90° 40′, measured on a transparent variety from North America. Cleavage parallel MM′. Fracture uneven, conchoidal. Hard. 7.5. Sp.gr. 3.104. Transparent to opaque. Lustre vitreous. Colour flesh-red to brownish and greyish-red.
Found generally in mica slate in Spain, France, and other parts of Europe, and lately in North America, in partially transparent crystals imbedded in quartz.

Hydrous silicates of alumina. A very uncertain series, several of which are, probably, only accidental mixtures in variable and indefinite proportions.

a. PHOLARITE, No. 187.
E J S. 6.364. Leon. 767.
Occurs in small, convex, nacreous scales.
Soft, friable. Colour white. Adheres to the tongue.
Found in the coal formations of Fins, Department Allier, France.

b. ALLOPHANE, No. 188.
Phil. 88. Haid. 3.69. Leon. 183.
Occurs in globular, reniform, and botryoidal masses. No cleavage. Fracture conchoidal. Hard. nearly 3.0. Sp gr. 1.85. Transparent, translucent. Lustre vitreous. Colour blue, green, brown, of several shades.
Found in limestone in Thuringia, at Schneeberg in Saxony, and probably in Derbyshire.
Some specimens, received in this Country under the name of Allophane, may be cleaved parallel to the planes of a rectangular solid, and are probably another Mineral.

c. LENZINITE. *Wallerite*, No. 189.
Phil. 87. Leon. 179.
Occurs in compact and earthy masses of various sizes.
Compact. Fracture conchoidal. Hard. 1.5. Sp.gr. 2.10. Transparent on the edges. Nearly dull. Colour yellowish milk-white. Streak shining. Feels rather greasy. In water it separates with noise into small fragments.
Earthy. Fracture earthy. Soft. Sp gr. 1.80. Slightly translucent, opaque. Dull. Colour snow-white. Streak shining.
Found at Kall in Eifeld.

d. HALLOYSITE, No. 190.
E.J.S. 6. 183.
Occurs in nodular masses. Structure compact. Fracture conchoidal. Nearly opaque. Lustre waxy. Colour bluish and greyish-white. Streak shining. Adheres to the tongue.
Found in the neighbourhood of Liege and Namur.
The analysis of this substance corresponds so nearly with that of Lenzinite as to leave little doubt of its being the same Mineral, but of a different colour.

e. SEVERITE, No. 191.
Phil. 87.
Occurs in small masses, nearly resembling Lithomarge. Fracture uneven. Hard. 1.0, 1 5. Slightly translucent. Dull. Colour white. Streak shining.
Found near St. Sever in France.

f FULLER'S EARTH, No. 192.
Phil. 52. Haid. 3.182.
Occurs massive in beds of considerable thickness. Fracture uneven, earthy. Soft. Sp.gr. 1.8, 2.2. Opaque. Dull. Colour greenish-brown, dull greywhite. Streak shining. Feels greasy.
Found in England, principally at Nutfield in Surrey, and in Stiria, Saxony, and some other places in Europe.

g. CIMOLITE, No. 193.
Phil. 54. Leon. 729.
Occurs in amorphous earthy masses, structure rather slaty. Fracture uneven, earthy. Soft. Sp gr. 2.0. Opaque. Colour greyish-white.
Found in the Island of Cimola, near Argenteria.
Used for the same purposes to which Fuller's earth is applied.

h. AGALMATOLITE. *Bildstein. Lardite. Pagodite.* No. 194.
Phil. 119. Haid. 3.100. Leon. 188.
Occurs massive. Fracture coarse, splintery. Soft. Sp.gr. 2.8. Slightly translucent. Colour white to brown, rather pale and dull. Streak shining. Unctuous to the touch.
Found in China, Transylvania, Saxony, and in Wales.
Cut into various figures by the Chinese, and seldom brought to this Country in any other state.

i. LITHOMARGE. *Steinmark*, No. 195.
Haüy, 4.558. Phil. 52. Haid. 3.183. Leon. 186.
Occurs massive. Spheroidal. Structure compact. Fracture large, conchoidal. Soft. Sp.gr. 2.2, 2.5. Opaque. Dull. Colour white, grey, red, yellow, blue. Streak shining. Adheres to the tongue. Unctuous to the touch.
Found in Saxony, and some other parts of Europe.
A *friable* variety is found at Ehrenfriedendorf in Saxony.

k BOLE, No. 196.
Phil. 53. Haid. 3.179. Leon. 191.
Occurs massive. Structure compact. Fracture conchoidal. Soft. Sp gr. 1.4, 2.0. Nearly opaque. Nearly dull. Colour brownish-black, red, yellow. Streak shining. Feels greasy. Adheres to the tongue.
Found in many places in trap rocks.
Several very different substances appear to have passed under this name, and it is doubtful if any one of them is correctly represented by the preceding description, yet we give it upon the authorites quoted.

l. MOUNTAIN SOAP, No. 197.
Phil. 53. Haid. 3.184. Leon. 192.
Occurs massive. Structure compact. Fracture fine earthy. Sectile. Opaque. Dull. Colour light brownish-black. Streak shining.
Found at Olkner in Poland.

m. LEMNIAN EARTH. *Terra sigillata*, No. 198.
Phil. 54. Leon. 191.
Occurs massive in the Isle of Lemnos. Fracture earthy. Soft. Opaque. Dull. Colour dull yellowish-grey and greyish-white.
An uncertain species.

n. KOLLYRITE, No. 199.
Phil. 88. Leon. 752.
Occurs massive, appearing like a tenacious white clay. When dry it splits into columnar masses like starch.
Found at Weissenfels in Thuringia.
The siliciferous Hydrate of Alumina, found in the

Pyrenees and analyzed by Berthier, probably belongs to this species.

o. SCARBRÖITE, No. 203.
P.M. and An. 5. 178.
Occurs as veins in the beds of sandstone covering the calcareous rock at Scarborough.
Fracture conchoidal. Hard. about 2.0. Sp.gr. about 1.48. Opaque. Dull. Colour white. Streak shining. Adheres to the tongue. Strong earthy smell when breathed upon. Does not become translucent, nor fall to pieces in water.

p. KAOLIN. *Porcelain Clay*, No. 201.
Phil. 51. Leon. 185.
Occurs massive and disseminated in decomposed granite rocks. Fracture fine earthy. Soft. Sp.gr. 2.2. Opaque. Dull. Colour yellowish and reddish-white.
Found in France, near Limoges and near Bayonne, and in Saxony, England, China, and other places.

q. CLAY, No. 202.
Phil. 55.56. Haid 3. 180.
Occurs massive. Structure earthy. Fracture uneven. Soft. Sp. gr. 1.8. 2.8. Opaque. Dull. Colour white, grey, brown, red, yellow, &c., of various shades, and striped, spotted, &c. Streak shining.
Found in all parts of the world.
The *Claystones* and *Slates* usually introduced into Catalogues of Minerals, appear too variable in their composition to admit of any distinct classification, and belong more properly to the geological series of rocks.

Siliciferous Sulphate of Alumina.

a. OLDHAMITE, No. 562.
An. 11.431.
Massive, and of the consistency of hog's-lard. Translucent. Colour, snow and milk-white. Taste, subacid. When exposed to the air, it dries and splits into long thin masses like starch, some of which are translucent and resemble gum arabic.
Found in a coal mine near Oldham in Lancashire.

Sulphate of Alumina.

a. WEBSTERITE. *Hallite*, No. 557.
Phil. 145. Haid. 3.70. Leon. 130.
Occurs in roundish or reniform masses, generally small. Fracture earthy. Soft, friable. Sp.gr. 1.7. Occasionally translucent, generally opaque. Colour white, sometimes yellowish. Streak white.
Found at Halle, in Prussia, in clay, and at Newhaven, Sussex, in limestone.

b. DAVITE, No. 558.
Q J. N S. 3.382. Leon. 433.
Occurs massive. Structure fine fibrous. Lustre silky. Colour white. Taste highly astringent. Very soluble.
Found near a warm spring which contains sulphuric acid, near Bogota, in Columbia.

Sulphate of Alumina and Potash.

a. ALUM, No. 559.
Haüy, 2.114. Phil. 196. Haid. 2.50. Leon. 107.
Occurs as an efflorescence, and sometimes in stalactites and fibrous masses.
Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the regular octahedron, indistinct. Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 1.75. Transparent, translucent. Lustre vitreous. Colour yellowish or greyish-white. Streak white. Taste astringent, sweetish.
Found in many parts of Europe.

b. ALUM-STONE. *Tolfaite*, No 563.
Haüy, 2.128. Phil. 196. Haid. 2.67. Leon. 131.
Occurs in attached crystals and massive.
Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 92° 50′. Cleavage parallel to the primary planes, and more distinctly perpendicular to the axis. Fracture uneven. Hard. 5.0. Sp.gr. 2.7. Transparent, translucent. Lustre vitreous. Colour pale greyish and reddish-white. Streak white.
Massive varieties, amorphous, structure granular, compact.
Found at Tolfa, near Rome, in Tuscany, Naples, Hungary, and occasionally in the neighbourhood of active volcanoes.

AMBLYGONITE, No. 501.
Phil. 198. Haid. 3.70. Leon. 283.
Occurs massive.
Cleavage parallel to the lateral planes of a rhombic prism of about 105° 45′, and indistinctly oblique to its axis. Fracture uneven. Hard. 6.0. Sp.gr. 3.04. Translucent. Lustre vitreous, inclining to pearly. Colour greenish-white. Streak white.
Found near Chursdorf in Saxony, in Granite, accompanying Tourmaline and Topaz.

AMMONIA.

Muriate of Ammonia.

a. SAL AMMONIAC, No. 60.
Haüy, 2.221. Phil. 194. Haid. 2.39. Leon. 587.
Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the octahedron. Fracture conchoidal. Hard. 1.5, 2. Sp.gr. 1.528. Transparent to opaque. Colour white, grey, greenish, yellowish, and brownish. Lustre vitreous. Taste saline and pungent.
Massive varieties, stalactitic, botryoidal and reniform, with a fibrous structure, and occasionally in crusts.
Found in the neighbourhood of active volcanoes, and occasionally in other situations. It sometimes occurs in the beds of coal near Newcastle.

Sulphate of Ammonia.

a. MASCAGNIN, No. 523.
Phil. 194. Haid. 3.125. Leon. 127.
Stalactitic and efflorescent. Semitransparent to opaque. Colour yellow and yellowish-grey. Taste acrid, bitter.
Found in the neighbourhood of volcanoes.

AMPHIBOLE, consisting of the following varieties:—
Common Hornblende, colour dark green or greenish-black.
Basaltic Hornblende.
Foliated Augite of Werner.
Blue Hyperstene of Giesecke.
Green Diallage of Hauy; *Smaragdite.*
Pargasite in short green crystals.
Actynolite; the crystals green, slender, and sometimes radiating.
Tremolite; *Calamite*; *Grammatite*; colourless or green, or pink, or brownish-grey, generally imbedded in dolomite, frequently fibrous, and sometimes radiating
Amianthoide; *Byssolite.*
Amianthus. Asbestus. No. 275 to 278.
Haüy, 2.372. 454. 481. Phil. 63. 71. Haid. 2.271. Leon. 493.

Primary form an Oblique rhombic prism. P,M = 103° 13′ M,M′ = 124° 30′. Cleavage parallel to MM′, and less distinctly to the planes of modification *h* and *k*. Fracture uneven. Hard. 5.0, 6.0. Sp.gr. 2.93 to 3.2, or according to Phil. 3.6. Transparent to opaque. Lustre vitreous, sometimes pearly. Colour white to black. Streak greyish.

Massive varieties differ considerably in structure; from slaty to columnar and fibrous; the fibres sometimes, as in amianthus, being silky and flexible.

Found in all parts of the world, and in various geological positions.

AMPELITE. *Black Chalk*, No. 203.

Phil. 55. Haid. 3.181.

Occurs massive. Structure fine granular, slaty. Fracture fine earthy Soft. Sp.gr. 2.11, 2.18. Opaque. Dull. Colour black. Streak rather shining.

Found in several parts of Europe in rocks of clay-slate.

ANALCIME. *Cubicite*, No. 210.

Haüy, 3.170. Phil. 129. Haid. 2.227. Leon. 202.

Occurs in attached and imbedded crystals. Primary form a Cube. CRYST. fig. 56. Cleavage parallel to P indistinct, interrupted. Fracture uneven. Hard. 5.5. Sp.gr. 2.068. Transparent to translucent. Lustre vitreous. Colour white, sometimes greyish and reddish. Streak white.

Found in several parts of Scotland, and in many different places in other Countries, chiefly in basaltic and amygdaloidal rocks.

ANORTHITE, No. 228.

Haid. 3.71. Leon. 432.

Occurs in attached crystals.

Primary form a Doubly oblique prism, CRYST. fig. 95. P,M=94°; P,T=110° 50′; M,T=117° 42′. Cleavage parallel to P and T. Fracture conchoidal. Hard. 6. Sp.gr. 2.76. Transparent to translucent. Lustre vitreous, and on P and T rather pearly. Colour white. Streak white.

Found in cavities in masses of Limestone, ejected from Vesuvius.

ANTHOPHYLLITE, No. 304.

Haüy, 2.600. Phil. 69. Haid. 2.211. Leon. 514. 432.

Occurs in crystalline masses, with a fibrous columnar structure.

Cleavage parallel to the lateral planes of a Rhombic prism of 125°, and to both its diagonals, the bright plane being parallel to the greater diagonal, and another imperfect cleavage transverse, and apparently perpendicular to the axis of the prism.

Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 3.2, 3.3. Translucent. Lustre pearly, and inclining to Metallic. Colour yellowish-brown. Streak white.

Found in beds of mica slate at Kongsberg and Modum in Norway.

ANTIMONY.

Arseniuret of Antimony?

a. ARSENICAL ANTIMONY, No. 38.

Leon. 719.

Occurs in botryoidal forms. Structure scaly. Fracture granular. Sp.gr. 6.2. Opaque. Dull. Colour tin-white.

Found at Przibram in Bohemia.

Native Antimony.

NATIVE ANTIMONY, No. 25.

Haüy, 4.79. Phil. 329. Haid. 2.426. Leon. 684.

Occurs in reniform or amorphous masses, with a granular structure, the grains being crystalline and differing considerably in size.

Primary form a Rhomboid. CRYST. fig. 106. P,P′= 117° 15′, as inferred from cleavage, no regular crystals having yet been observed. Hard. 3.0, 3.5. Sp.gr. 6.646. Opaque. Lustre metallic. Colour tin-white. Streak the same.

Found in veins traversing ancient rocks, at Sahlberg in Sweden, at Allemont in Dauphiny, and at Andreasberg in the Hartz.

The arseniferous native antimony appears to be an accidental mixture of arsenic with native antimony.

Oxide of Antimony.

a. WHITE ANTIMONY. No. 409.

Haüy, 4 308. Phil. 331. Haid. 2.251. Leon. 335.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′=136° 58′. Cleavage parallel to M,M′. Lustre adamantine. Fracture indistinct. Hard. 2.5, 3.0. Sp.gr. 5.566. Translucent. Colour white, sometimes reddish or greyish. Streak white.

Massive variety, earthy, investing sulphuret and native antimony, and apparently produced by the decomposition of those Minerals.

Found in Bohemia, Saxony, Hungary, and France.

Sulphuret of Antimony.

a. GREY ANTIMONY, No. 93.

Haüy, 4.291. Phil. 329. Haid. 3. 23. Leon. 605.

Occurs in attached and aggregated crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 90° 45′. The crystals sometimes capillary and flexible, like silky fibres. Cleavage parallel to diagonal of the prism. Fracture uneven. Hard. 2.0. Sp.gr. 4.62. Opaque. Lustre metallic. Colour between lead and steel-grey, frequently with a yellow and blue tarnish. Streak the same.

Massive varieties, amorphous, structure large fibrous, foliated, compact.

Found in Hungary, France, England, Scotland, the Hartz, Saxony, and other places.

b. BLACK ANTIMONY? No. 94.

Leon. 719.

Occurs as a black powder in cavities in Hornstone.

Found at Joachimsthal in Bohemia.

Sulphuret of Antimony and Nickel.

a. HARTMANNITE, No. 96.

Haid. 3.131. Leon. 615.

Occurs in imbedded crystalline particles and masses.

Primary form, according to Haidinger, a Cube. CRYST. fig. 56. Cleavage parallel to P. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 6.451. Opaque. Lustre metallic. Colour whitish steel-grey. Streak the same.

Massive variety, amorphous. Structure granular.

Found in the Principality of Nassau.

Sulphuret of Antimony, Lead, and Iron.

a. JAMESONITE, No. 101.

Haid. 3.26. Leon. 748.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 101° 20′ nearly. Haid. Cleavage

parallel to P distinct, less so parallel to M. Fracture very indistinct. Hard. 2.0, 2.5. Sp.gr. 5.564. Opaque. Lustre metallic. Colour steel-grey, sometimes dark. Streak the same.

Massive variety, amorphous. Structure large to small fibrous.

Found in Cornwall and in Hungary, and probably in other places, where it has been considered a sulphuret of antimony.

Sulphuret of Antimony and Lead.

a. ZINKENITE, No. 99.

E.J.S. 6.17, 358.

Occurs in attached crystals, said to be regular hexagonal prisms, and massive.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ uncertain. No cleavage. Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 5.303. Opaque. Lustre metallic, bright. Colour steel-grey. Streak the same.

Found at Wolfsberg in the Hartz.

Sulphuret of Antimony and Iron.

a. BERTHIERITE, No. 102.

E.J.S. 7 353.

Occurs in confused laminated masses, or elongated imbedded prisms, resembling grey antimony. Colour dark steel grey inclining to brown.

Found at Chazelles in Auvergne.

Oxi-sulphuret of Antimony.

a. RED ANTIMONY, No. 410.

Haüy, 4.311. Phil. 331. Haid. 3.36. Leon. 608.

Occurs in thin, acicular crystals, generally radiating, sometimes promiscuously aggregated.

Primary form, according to Phillips, a Square prism, and according to Haidinger an oblique rhombic prism. One bright cleavage, and others less distinct. Hard. 1.0, 1.5. Sp.gr. 4.5. Translucent. Lustre adamantine. Colour dull red.

Found at Braunsdorff in Saxony, in Hungary, France, and in the Hartz.

APLOME, No 296.

Haüy, 2 538. Phil. 29. Haid. 2.364. Leon. 491.

Occurs in attached and imbedded dodecahedral crystals.

Primary form a Cube. CRYST. fig. 56. Surfaces of the Dodecahedron striated parallel to the edges of P. Cleavage imperfect parallel to P. Fracture uneven. Hard. 7.0, 7.5. Sp.gr. 3.444. Translucent, opaque. Lustre vitreo-resinous. Colour yellowish-brown.

Found in Saxony, Bohemia, Siberia, and in small crystals in England.

APOPHYLLITE. *Albin. Ichthyopthalmite. Tesselite. Oxahverite*, No. 204.

Haüy, 3.191. Phil. 110. Haid. 2 245. Leon. 213.

Occurs in attached crystals and massive.

Primary form a Square prism. CRYST. fig. 65. M,*a* = 109° 40′. Cleavage parallel to P, perfect; less so parallel to M. Fracture uneven. Hard. 4.5, 5.0. Sp.gr. 2.46. Transparent, translucent. Lustre vitreous. Colour white, occasionally with a yellowish, greenish, or reddish tinge. Streak white.

Massive variety, amorphous, structure laminar.

Found in the cavities of trap rocks, and occasionally in beds of the older formations, in the Faroe Islands, in India, Sweden, Norway, the Bromart, Bohemia, and some other places. The Oxahverite from Oxahver in Iceland.

ARFWEDSONITE, No. 279.

Phil. 377. Haid. 3. 73. Leon. 497.

Occurs massive amorphous. No crystalline form observed.

Cleavage parallel to the lateral planes, and both the diagonals of a Rhombic prism of 123° 55′. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 3.44. Opaque. Lustre vitreous. Colour black.

Found in Norway, and in Greenland associated with Sodalite.

ARSENIC.

Native Arsenic.

a. NATIVE ARSENIC, No. 27.

Haüy, 4.236. Phil. 275. Haid. 2.423. Leon. 676

Occurs in reniform stalactitic and amorphous masses, frequently in parallel layers. Structure fine granular. Fracture uneven. Hard. 3.5. Sp gr. 5.766. Opaque. Colour of fresh fracture greyish-tin-white, which afterwards becomes greyish-black. Streak shining.

Found in several parts of Saxony, in Bohemia, the Hartz, France, Norway, Transylvania, and other places; generally in metallic veins.

Oxide of Arsenic.

a. OXIDE OF ARSENIC, No. 465.

Haüy, 4.241. Phil. 375. Haid. 2.26. Leon. 333. 170.

Occurs in attached octahedral crystals and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the octahedron. Fracture conchoidal. Sp.gr. 3.7. Translucent, opaque. Lustre nearly adamantine. Colour white, occasionally yellowish. Streak white. Taste sweetish astringent.

Massive varieties, reniform, botryoidal, stalactitic, and amorphous.

Found accompanying native arsenic in many mineral veins, and produced from the decomposition of other Minerals. Is soluble in water and a violent poison.

Red Sulphuret of Arsenic.

a. REALGAR, No. 108.

Haüy, 4 247. Phil. 277. Haid. 3.49. Leon. 602.

Occurs in attached crystals and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 104° 6′, M,M′ = 74° 15′. Cleavage parallel to P and M. Fracture conchoidal.

Hard. 1.5, 2.0. Sp.gr. 3.556. Transparent, opaque. Lustre resinous. Colour red. Streak orange-yellow.

Massive varieties, amorphous, structure granular.

Found principally in Hungary and Transylvania, also in Saxony, Bohemia, and some other places.

Yellow Sulphuret of Arsenic.

a. ORPIMENT, No. 109.

Haüy, 4.247. Phil. 277. Haid. 3.47. Leon. 599.

Occurs in imbedded imperfect crystals and massive.

Primary form a Right rhombic prism. CRYST. fig 71. M,M′ = 100°. Cleavage parallel to the greater diagonal of the prism. Fracture uncertain. Hard. 1.5, 2.0. Sp.gr. 3.480. Translucent. Lustre resinous. Colour yellow. Streak paler yellow.

Massive varieties, botryoidal, reniform, nodular, sometimes granular, the structure of the grains or masses foliated, and the laminæ very flexible

Found in most of the districts which yield the red sulphuret, and is like that used as a pigment.

AURALITE, No. 330.
Occurs in apparently hexagonal prisms in felspar at Abo in Finland. Opaque. Colour dark brown.

AXINITE. *Thumite. Yanolite*, No 430.
Haüy, 2.559. Phil. 43. Haid. 2.341. Leon. 454.
Occurs in attached and imbedded crystals, and massive.
Primary form a Doubly oblique prism. CRYST. fig. 95. P,M = 134° 40′. P,T = 115° 17′. M,T = 135° 10′. Fracture uneven. Hard. 6.5, 7.0. Sp.gr. 3.27. Transparent, translucent. Lustre vitreous. Colour bluish, greyish, reddish-brown, of several shades. Streak white.
Massive varieties, amorphous, structure lamellar, granular.
Found in Dauphiny, and at Botallack in Cornwall, and in other places.

AZOTIC GAS, No. 44.
Is said to be contained in the Bath hot springs, and to rise with the vapour from the public bath.

AZURITE. *Klaprothite. Tyrolite. Voroulite*, No. 499.
Haüy, 3.54. Phil. 94. Haid. 2.290. Leon. 136.
Occurs in attached crystals and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 121° 30′. Cleavage indistinct. Fracture uneven. Hard. 5.0, 5.5. Sp gr. 3.056. Translucent, opaque. Lustre vitreous. Colour blue Streak white.
Massive varieties, amorphous, structure granular.
Found in Salzburg, and in rolled crystalline masses in Brazil.

AMPHODELITE, No. 331.
A Mineral found in Finland, having the form, cleavage, and colour of Latrobite.

BABINGTONITE, No. 332.
Haid. 3.75. Leon. 721.
Occurs in attached crystals.
Primary form a Doubly oblique prism. CRYST. fig. 95. P,M = 92° 34′. P,T = 88°. M,T = 112° 30′. Cleavage parallel to P and T. Fracture uneven. Hard. 5.5, 6.0. Faintly translucent. Lustre vitreous. Colour black, sometimes greenish.
Found at Arendal in Norway, associated with Cleavelandite.

BARYTES.

Carbonate of Barytes.

a. WITHERITE. *Barolite*, No. 438.
Haüy, 2.25. Phil. 182. Haid. 2.119. Leon. 330.
Occurs in attached crystals and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 118° 30′. Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 4.3. Transparent, translucent. Lustre vitreo-resinous. Colour white, sometimes greyish or yellowish. Streak white.
Massive varieties, globular, botryoidal, reniform. Structure large, fibrous, sometimes granular.
Found principally in England, in Shropshire, Lancashire, Durham, and Westmoreland, and occasionally in small quantities in Siberia, Hungary, and other places.

Carbonate of Lime and Barytes.

a. BARYTO CALCITE, No. 443.
Haid. 3.76. Leon. 327.
Occurs in attached crystals and massive.
Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 102° 54′. M,M′ = 106° 54′. Cleavage parallel to P and M, distinct. Fracture uneven. Hard. 4 0. Sp.gr. 3.66. Transparent, translucent. Lustre vitreo-resinous. Colour white, sometimes yellowish or greenish. Streak white.
Massive varieties, amorphous. Structure granular.
Found at Alston Moor, Cumberland.

Sulphate of Barytes.

a. BAROSELENITE. *Bolognian Spar. Cauk*, No. 527.
Haüy, 2.5. Phil. 183. Haid. 2.121. Leon. 255.
Occurs crystallized and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 101° 42′. Cleavage parallel to P and M. Fracture conchoidal. Hard. 3 0, 3.5. Sp gr. 4 416, 4.7. Transparent, translucent. Lustre vitreous. Colour white, blue, yellow, brown. Streak white.
Massive varieties, occasionally globular, reniform, amorphous. Structure fibrous, granular, compact.
Found in several localities in most Countries, and in different geological positions.

Sulphate of Barytes and Fluate of Lime.

a. BARYTO-FLUORITE, No. 528.
An. 16.48.
Occurs in a vein in coarse shell limestone in Derbyshire, and nearly resembles fine compact grey limestone. Hard. 4. Sp gr. 3.75.

BERGMANNITE. *Spreüstein. Radiolite of Esmark*, No. 333.
Haüy, 4.484. Phil. 290. Haid .3.77. Leon. 474.
Occurs massive, amorphous. Structure fibrous, sometimes radiating. Hard. 7.0, 7.5. Sp.gr. 2 3 Opaque. Colour greyish-white, dull yellow, and red. Lustre pearly.
Found near Stavern in Norway.

BIOTINE, No. 334.
The crystals of this substance appear to correspond in form and measurement with those of Anorthite, of which they will probably be found to be a variety.

BISMUTH.

Arseniuret of Bismuth?

ARSENICAL BISMUTH, No. 34.
Haid. 3.74. Leon. 720.
Occurs in aggregations of small globular forms. Structure fibrous or curved lamellar. Fracture uneven. Soft. Heavy. Lustre resinous. Colour dark hair-brown.
Found at Schneeberg in Saxony.

Carbonate of Bismuth.

AGNESITE, No. 456.
B.M. Tab. 344. Phil. 271. Leon. 787.
Resembles steatite, but more earthy, and harsher to the touch.
Found at St. Agnes, Cornwall.

Silicious Carbonate of Bismuth.

BISMUTH-BLENDE, No. 457.
E J.S. 7.342.
Occurs in attached crystals, and in globular and stalactitic masses.
Primary form a Cube. CRYST. fig. 56. Cleavage imperfect. Fracture conchoidal. Hard. 4.5, 5.0. Sp.gr. 5.9, 6 0. Translucent, opaque. Lustre bright resinous. Colour reddish and yellowish-brown. Streak yellowish-grey.
Found at Schneeberg in Saxony.

NATIVE BISMUTH, No. 9.
Haüy, 4.202. Phil. 272. Haid. 2.433 Leon. 693.

Mineralogy

Occurs crystallized and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to planes of *Mod. a.* Fracture indistinct. Hard. 2.01, 2.5. Sp.gr. 9.737. Opaque. Lustre metallic. Colour of fresh cleavage reddish-silver-white, but tarnishes on exposure to air. Streak unchanged.

Massive varieties, amorphous, structure granular.

Found in several mines in Saxony, and in most other mining districts of Europe.

Oxide of Bismuth.

a. BISMUTH OCHRE, No. 137.

Haüy, 4.214. Phil. 274. Leon. 561.

Occurs massive, amorphous, sometimes minutely disseminated. Fracture earthy. Soft. Sp.gr. 4.7. Opaque, Dull. Colour greenish or greyish-yellow.

Found in Saxony and Bohemia.

Seleniuret of Bismuth and Tellurium.

a. BASINATITE, No. 46. Leon. 589.

Occurs in small, imbedded, laminated masses. Sp.gr. 7.8 Lustre metallic. Colour between steel and lead-grey.

Found at Bastnaes in Sweden.

Sulphuret of Bismuth.

a. BISMUTH GLANCE, No. 84.

Haüy, 4 210. Phil. 273. Haid. 3.19. Leon. 616.

Occurs in attached and imbedded crystals, and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M' about 91°. Cleavage parallel to P, and to the greater diagonal of the prism. Fracture indistinct. Opaque. Lustre metallic. Colour lead to steel-grey. Streak the same.

Massive varieties, amorphous, structure granular or fibrous, the fibres promiscuously aggregated.

Found sparingly in Saxony, Bohemia, Hungary, and some other places in Europe, and in England in Cornwall and Cumberland.

Sulphuret of Bismuth and Copper.

a. CUPREOUS BISMUTH, No. 85.

Phil. 271. Haid. 3.91. Leon. 619.

Occurs massive. Structure small-fibrous. Fracture uneven. Opaque. Lustre metallic. Colour lead-grey to steel-grey.

Found at Fürstenberg, in veins accompanying other ores of bismuth, cobalt, &c.

Sulphuret of Bismuth, Lead, and Copper.

a. NEEDLE ORE, No. 86.

Phil. 274. Haid. 3.130. Leon. 618.

Occurs in imbedded prismatic crystals, in quartz.

Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 6.125. Opaque. Lustre metallic. Colour dark lead-grey.

Found near Catharinenburg in Siberia.

Sulpho-telluret of Bismuth.

a. BORNITE. *Telluret of Bismuth*, No. 20.

Occurs in imbedded, imperfect, rhombic and hexagonal crystals, and small foliated masses.

Primary form a Rhomboid. CRYST. fig. 106. The crystals macled in several directions. Cleavage perpendicular to the axis, very distinct Sp.gr. 7.5. Lustre highly metallic. Colour bright steel-grey.

Found at Schoubkan, near Schemnitz, Hungary.

BORACIC ACID. *Sassolin*, No. 423.

Haüy, 1.297. Phil. 144. Haid. 2.25. Leon. 146.

Occurs naturally in scaly or granular crystalline aggregations, which are very friable.

Translucent. Lustre pearly. Colour greyish and yellowish-white. Streak white. Taste slightly acid and bitter. Sp.gr. 1.480.

Found at Volcano, one of the Lipari Islands, and in other volcanic districts.

BOVELITE. *Pseudo Sommite*, No. 335.

Phil. 126. Leon. 468.

Occurs in attached hexagonal prisms.

Primary form a Rhomboid. CRYST. fig. 106. Transparent. Lustre vitreous. Colour white. Streak white.

Found at Capo di Bova, near Rome, and has hitherto been distinguished from Nepheline only by its *not gelatinizing in acids* as that Mineral does. Its secondary forms, if observed, have not been described.

BREISLAKITE, No. 568.

Haid. 3.80. Leon. 723.

Occurs in capillary brownish fibres, covering and filling cavities in some of the substances ejected from Vesuvius. It is said to contain a considerable portion of copper, but its other constituents are not known.

BREWSTERITE, No. 216

Phil. 200. Haid. 3.80. Leon. 193, 723.

Occurs in attached crystals.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M about 92°, M,M' = 136°. Cleavage parallel to the oblique diagonal. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.2. Transparent, translucent. Lustre vitreous. Colour yellowish and greyish-white, and occasionally colourless.

Found at Strontian in Scotland.

BRONZITE. No. 286.

Haüy, 2.455. Phil. 25.71. Haid. 2.207. Leon. 518.

Occurs in massive aggregations of columnar crystals.

Cleavage parallel to the lateral plane and both diagonals of a Rhombic prism of 93° 30'. Fracture uneven. Hard. 4.0, 5.0. Sp.gr. 3.25. Translucent. Lustre vitreous, pseudo-metallic on cleavage planes. Colour greenish or greyish-brown. Streak lighter colour.

Found in serpentine in Stiria, in greenstone in the Hartz, and in other places.

BUCKLANDITE, No. 336.

An. N.S. 7.134. Haid. 3.83. Leon. 725.

Occurs in attached crystals.

Primary form an Oblique rhombic prism. P,M = 103° 56'. M,M' = 70° 40'. Levy. Opaque. Colour dark brownish-black.

Found near Arendal in Norway, and at Laach on the Rhine.

BUSTAMITE, No. 274.

S. 18.392.

Structure bladed. Hard. 6.5. Sp.gr. 3.1, 3.3. Nearly opaque. Colour grey, greenish, and reddish.

Found in Mexico.

CADMIUM. A metal found in small quantities accompanying zinc in several of its ores, particularly in the fibrous blende from Przibram in Bohemia.

CARBON.

A. DIAMOND, No. 40.

Haüy, 4.419. Phil. 361. Haid. 2.306. Leon. 669.

Mineralogy

Occurs in imbedded crystals in alluvial ground.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the regular octahedron, very distinct. Fracture conchoidal. Hard. 10.0. Sp.gr. 3.52. Transparent, but sometimes rendered opaque by foreign matter. Lustre adamantine. Colour white, sometimes grey, blue, green, yellow, red, brown, black. Streak greyish.

Found in the East Indies and in Brazil.

B. COAL.

a. *Not bituminous.* ANTHRACITE, No. 41.

Haüy, 440. Phil. 364. Haid. 3.64. Leon. 672. 803.

Occurs massive, amorphous. Structure columnar, compact. Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 1.4, 1.5. Opaque. Lustre imperfect metallic. Colour grey to iron-black. Streak the same.

Found in most Countries.

b. *Bituminous*, No. 586.

Haüy, 4.159, 470. Phil. 370, 371. Haid. 3.61. Leon.

This includes the *common*, the *Cannel*, and all the varieties of fossil coal.

Occurs massive, amorphous. Structure foliated, granular, compact, earthy, and resembling wood. Fracture conchoidal, uneven. Lustre resinous, of different degrees. Colour black, brown, brownish, and greenish-yellow.

Found in most parts of the World, associated with vegetable organic remains.

c. *Wood Coal.* LIGNITE. No. 574.

Phil. 372.

Occurs massive. Structure fibrous, compact, resembling wood. Fracture of some varieties conchoidal. Opaque. Lustre resinous, dull. Colour brown, of several shades, to black.

Found in several parts of Europe and America.

d. *Paper Coal.* DYSODILE. No. 575.

N.J. 24 223. Phil. 372.

Occurs in amorphous masses. Structure foliated, the leaves thin and a little flexible. Sp.gr. 1.146. Opaque, but becomes translucent after immersion in water. Colour greenish and yellowish-grey. When burned it produces a strong and fetid bituminous odour.

Found in a thin stratum between two beds of secondary limestone at Melilli, near Syracuse in Sicily.

C. BITUMEN.

Haüy, 4 452. Phil. 366 to 369. Haid. 3.59. Leon. 797. 799. 801.

a. *Liquid.* NAPHTHA. No. 580.

Transparent. Colourless, or slightly tinged with yellow. Odour peculiar, termed bituminous.

Found chiefly on the coast of the Caspian Sea.

b. *Viscid.* PETROLEUM, No. 581.

Slightly translucent. Colour dark reddish-brown. Odour bituminous.

Found in many parts of Europe and America, but chiefly in Asia, flowing from beds associated with coal strata. As much as 400,000 hogsheads is said to be collected annually in the Birman Empire. It is also abundant in Persia.

c. *Elastic.* ELATERITE, No. 582.

Soft, flexible. Opaque. Colour brown, sometimes greenish. Odour bituminous.

Found only in the Odin mine, near Castleton, Derbyshire.

d. *Earthy.* MALTHA.

Less free from extraneous matter than the preceding varieties, to which circumstance it probably owes its earthy character.

Fracture uneven. Soft. Opaque. Colour blackish-brown. Odour bituminous.

Found chiefly in Persia, and less frequently in other places than the other varieties.

e. *Earthy, containing Benzoic Acid.* MURINDO.

Q.J. N.S. 3 387.

Occurs massive. Fracture earthy. Yields to the nail. Floats in water. Opaque. Dull. Colour externally blackish-brown, internally lighter. Tastes hot and peculiar. Smell pungent.

Found at Murindo, Province of Choco, Columbia.

f. *Compact.* ASPHALTUM. *Jew's Pitch*, No. 585.

Fracture conchoidal. Hard. 2. Sp.gr. 1.16. Opaque. Lustre vitreous, resinous. Colour brown to black.

Found in Albania, on the shores of the Dead Sea, in considerable quantities; in the Islands of Barbadoes and Trinidad, and occasionally in other places.

It is supposed to have been used by the Egyptians in embalming the bodies of the dead, and has been employed in the West Indies instead of pitch for calking the bottoms of ships.

These varieties of bitumen pass by insensible degrees from the transparent fluid to the opaque solid, and hence they are regarded as appertaining to the same Mineral species.

D. RETINASPHALTUM, No. 577.

Phil. 375. Haid. 3.146. Leon. 793.

Occurs in amorphous lumps of different sizes, imbedded in wood coal. Fracture imperfect, conchoidal. Hard. 1.5, 2.0. Sp.gr 1 135. Opaque. Lustre resinous. Colour pale brownish-yellow.

Found at Bovey Tracey, Devonshire, and is also said to have been found at Halle and some other places on the Continent, accompanying earthy brown coal, and of different colours.

E. FOSSIL COPAL. *Highgate Resin*, No. 578.

Phil. 375.

Found in blue clay at Highgate near London, and at Wolchow in Moravia, in small nodular masses. Fracture conchoidal. Sp gr. 1.046. Nearly opaque. Lustre resinous. Colour dull brown.

F. AMBER, No. 576.

Phil. 373. Haid. 3.57. Leon. 791.

Occurs in nodular masses, sometimes very small. Fracture conchoidal. Hard. 2.0, 2.5. Sp gr. 1.08. Transparent to opaque. Lustre resinous. Colour yellowish-white, brown, red, yellow. Streak white.

Found on the coasts in the Baltic, and in beds of wood coal in several places in Europe and other Countries.

G. HATCHETINE. *Mineral Adipocire*, No. 579.

An. 1.136. Phil. 374. Haid. 3.106. Leon. 795.

Occurs in thin flakes and in granular masses in cavities of lime or ironstone. Very soft and light. The flakes translucent, with a slightly *glistening* and pearly lustre, the granular masses opaque and dull. Colour yellowish-white, and wax and greenish-yellow, without odour and not elastic. Combustible.

Found at Merthyr Tydvil in South Wales.

H. NATIVE NAPHTHALINE, No. 587.

Q.J. 4.446.

Occurs crystalline, cleavable in some directions, with

a conchoidal fracture in others. Sp.gr. 1.0, 1.5. Transparent. Lustre adamantine. Colour white, yellow, green. Has the appearance of Talc.

Found in the fissures of bituminous wood in the coal formation of Urnach, Canton of St. Gall.

r. SCHERERITE, No. 588.

Q.J. 5.431.

Occurs between the fibres of fossil wood in acicular crystals, and small layers. Translucent. Lustre nacreous. Colour white or yellowish white.

Found at Urnach, Canton of St. Gall, Swisserland, in a coal formation.

CAVOLINITE, No. 337.

The crystalline forms of this Mineral correspond very nearly with those of Nepheline and Davyne; but its lustre is highly pearly instead of vitreous, and it may be cleaved with much greater facility. It is found at Mount Vesuvius.

CEREOLITE, No. 338.

The Marquis de Dree first gave this name to a soft yellowish waxy looking substance occurring in a greyish matrix, in small irregular nodules. Several other soft Minerals, differing in many of their characters from that of De Dree, have since passed under the same name, but there do not appear to be any published descriptions or analyses of them.

De Dree's Mineral was found near Lisbon.

CERIUM.

a. CARBONATE OF CERIUM, No. 455

E.J.S. 3.331. Leon. 726.

Occurs in white crystalline coatings on the Cerite of Bastnaes, in Sweden.

b. FLUATE OF CERIUM, No. 509.

Phil. 266. Haid. 3.100. Leon. 571.

Is said to occur in six-sided prisms, plates, and amorphous masses. Colour reddish. No other characters given.

Found very sparingly at Finbo, Broddbo, and Bastnaes, near Fahlun, in Sweden.

c. SUB-FLUATE OF CERIUM, No. 510.

Phil. 266. Haid. 3.101. Leon. 243.

Resembles porcelain jasper, but with traces of crystallization. Colour yellow.

Found at Finbo in Sweden.

d. FLUATE OF CERIUM AND YTTRIA, No. 511.

Phil. 267. Haid. 3.101.

Occurs in small imbedded masses, and sometimes thinly investing Gadolinite. Earthy. Soft. Colour red, of different shades, yellow, white.

Said, by Berzelius, to be a mechanical mixture of the fluates of yttria and of cerium with silica.

e. YTTRO-CERITE. *Fluate of Cerium, Yttria, and Lime,* No. 512.

Phil. 265. Haid. 3.172. Leon. 573.

Occurs massive, structure granular, compact. Fracture uneven. Hard. 6.5. Sp.gr. 3.447. Opaque. Colour violet-blue, greyish-red, and greyish-white.

Found at Finbo and Broddbo in Sweden.

f. SILICATE OF CERIUM. No. 171.

E.J.S. 6.357. Leon. 227.

Occurs in small imbedded nodules and hexagonal prisms, in magnesian carbonate of lime. Cleavage parallel to the lateral planes. Fracture uneven. Translucent. Colour pale yellowish-brown.

Found at Santa Fé de Bogota, accompanying the precious Emeralds from that locality.

Silicate of Cerium and Iron.

a. CERITE, No. 170.

Haüy, 4.393. Phil. 263. Haid. 2.394. Leon. 227.

Occurs in amorphous imbedded masses. Structure fine granular. Fracture uneven. Hard. 5.5. Sp.gr. 4.912. Slightly translucent. Lustre resinous. Colour pale dull red, sometimes greyish. Streak white.

Found near Riddarhittan in Sweden, imbedded in or accompanying Cerine.

b. CERINE, No. 319.

Haüy, 4.395. Phil. 265. Haid. 2.395. Leon. 481.

Occurs massive, and rarely in attached imperfect crystals. Hard. 5.5, 6.0. Sp gr. 4.173. Opaque. Lustre imperfect metallic. Colour brownish black. Streak brownish-grey.

Found near Riddarhittan in Sweden.

c. ALLANITE, No. 320.

Haid. 3.68. Leon. 481.

Occurs crystallized and massive.

Primary form is said by Phillips to be a Square prism, and by Haidinger, a Doubly oblique prism, whence it appears that two different Minerals have been described under the same name. Fracture, according to Haidinger, imperfect conchoidal. Hard. 6.0. Sp gr. 4.0. Opaque. Lustre imperfect metallic. Colour brownish-black. Streak greenish-grey.

Found at Alluk, East Greenland.

The Allanite of Phillips is probably the Fergusonite of Haidinger.

Silicate of Cerium, Iron, Alumina, and Lime.

a. ORTHITE, No. 327.

Phil. 265. Haid. 3.133. Leon. 210.

Occurs in small, slender, columnar, imbedded masses. Fracture conchoidal. Hard. 6.0, 7.0. Sp.gr. 3.288. Opaque. Lustre vitreous. Colour brownish-black. Streak brownish-grey.

Found at Finbo in Sweden, in a granitic vein, traversing gneiss, and, in larger imbedded masses, in Finland.

b. PYRORTHITE, *containing Carbon*, No. 328.

Phil. 265. Haid. 3.142. Leon. 773.

Occurs in single or aggregated, slender, columnar masses, imbedded in granite or quartz. Fracture conchoidal, uneven, earthy. Haid. 2.5. Sp.gr. 2.19. Opaque. Lustre resinous. Colour brownish-black. the same.

Found near Fahlun in Sweden.

CHABASIE, No. 205.

Haüy, 3.163. Phil. 138. Haid. 2.232. Leon. 198.

Occurs in attached crystals.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ =94° 46′. Cleavage parallel to P, nearly distinct. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 2.1. Transparent, translucent. Lustre vitreous. Colour white, sometimes reddish or yellowish. Streak white.

Found in the Faro Islands, in Iceland, in many parts of Europe, and in America.

CHIASTOLITE. *Crucite. Macle,* No. 186.

Haüy, 2.365. Phil. 201. Haid. 3.84. Leon. 726.

Occurs in imbedded crystals in clay-slate.

Primary form unknown. The crystals are nearly

Square prisms, composed of a greyish or reddish substance, enclosing a central black prism, and occasionally four others within its lateral edges, connected with the central one by four black thin plates.

Cleavage parallel to the lateral planes. Fracture splintery. Hard. 5.0, 5.5. Sp.gr. 2.944. Translucent, opaque. Lustre vitreo-resinous. Colour greyish and yellowish, or reddish-white. Streak white.

Found in many parts of Europe and America.

CHILDRENITE, No. 502.

Q.J.S. 16.274. Haid. 3 85. Leon. 137. 728.

Occurs in minute attached crystals.

Primary form a Right rhombic prism. M,M=92° 48′. Fracture uneven. Hard. 4.5, 5.0. Transparent, translucent. Lustre vitreous. Colour yellow. Streak white.

Found in the neighbourhood of Tavistock in Devonshire, and at Crinnis in Cornwall.

CHLOROPHAEITE, No. 173.

Macculloch, Western Isles, 1.504. Phil. 202. Haid. 3.86. Leon. 729.

Occurs in small masses imbedded in basalt. Fracture conchoidal. May be scratched by a quill. Sp.gr. 2.02. Transparent, opaque. Lustre vitreous. Colour green when first broken, but afterwards becomes black.

Found in the Isle of Rum, in Fifeshire, and in Iceland.

OXIDE OF CHROME, No. 419.

Phil. 271. Leon. 557.

Occurs in compact or pulverulent masses, coating or filling cavities in the chromate of iron at Unst, one of the Shetland Isles. Structure of the compact approaches to crystalline. Translucent. Lustre resinous. Colour grass-green and pale-yellow.

It is also found colouring granular quartz at Ecouchetz in Burgundy.

CHRYSOBERYL. *Cymophane*, No. 324.

Haüy, 2.303. Phil. 89. Haid. 2.304. Leon. 539.

Occurs in loose crystals in alluvial deposits in Brazil, and in imbedded crystals at Haddam and Saratoga, North America.

Primary form a Right rhombic prism. M,M′=120°. Cleavage parallel to P, and to the short diagonal of the prism. Fracture conchoidal. Hard. 8.5. Sp.gr. 3.754. Transparent, translucent. Lustre vitreous. Colour yellowish and brownish-green. Frequently with a bluish opalescence. Streak white.

Found in Brazil and North America.

CHUSITE, No. 339.

Phil. 202. Leon. 533.

A Mineral found by Saussure in the porphyritic rocks near Limbourg, and imperfectly described as occurring massive or granular. Translucent. Lustre greasy.

CLEAVELANDITE. *Albite. Silicious Spar*, No. 227.

Haüy, 3.70. Phil. 113. Haid. 2.255. Leon. 417.

Occurs in attached crystals and massive.

Primary form a Doubly oblique prism. P,M=93° 30′. P,T=115°. M,T=119° 30′. Cleavage parallel to the primary planes. Fracture uneven. Hard. 6.0. Sp.gr. 2.61, 2.68. Transparent, translucent. Lustre vitreous. Colour white, grey, pale blue, greenish, red. Streak generally white.

Massive varieties amorphous. Structure laminar.

Found in Dauphiny, at St. Gothard, and generally accompanying felspar in most of its numerous localities.

COBALT.

Arseniate of Cobalt.

a. RED COBALT. *Cobalt bloom*, No. 472.

Haüy, 4.232. Phil. 281. Haid. 2.181. Leon. 162.

Occurs sometimes in attached thin crystals, but generally as fine fibres, forming small globular tufts, or evenly coating the matrix, and also pulverulent and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M=101° 13′. M,M′=55° 15′. Cleavage parallel to a plane passing through the oblique diagonal, very distinct. Hard. 1 5, 2 0. Sp gr. 2.948. Transparent, translucent. Lustre vitreous. Colour red, of various shades, sometimes pearl or greenish-grey. Streak lighter colour. Splits easily into thin laminæ, which are very flexible.

Massive variety amorphous; structure fibrous, often radiating.

Found principally in Saxony and Bohemia.

b. ROSELITE? No. 473.

An. N.S. 8 439.

Occurs in attached crystals on greyish quartz.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′=125° 7′. Cleavage parallel to P. Fracture conchoidal. Hard. 3.0. Translucent. Lustre vitreous. Colour deep rose-red.

Found at Schneeberg in Saxony.

Arseniuret of Cobalt.?

a. WHITE COBALT, No. 29.

Haüy, 4.219. Phil. 278. Haid. 2.452. Leon. 654. 680.

Occurs in imbedded crystals, generally single, and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the primary planes, very distinct. Fracture uneven. Hard. 5.5. Sp.gr. 6.3. Lustre metallic. Colour silver-white. Streak greyish-black.

Massive variety amorphous; structure granular.

Found in Norway; in fine crystals at Tunaberg in Sweden; in Silesia, and in Cornwall.

b. HARD WHITE COBALT, No. 30.

E.N.P.J. 3.271.

Occurs crystallized. Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the cube distinct; less so parallel to *Mod. a*, and still less parallel to *Mod. e*. Sp.gr. 6.74, 6.84. Distinguished from white cobalt by its more distinct cleavage and greater sp.gr.

Found at Skutterud in Norway.

c. RADIATED WHITE COBALT, No. 31.

Haid. 2.454. Leon. 162?

Is said to crystallize in Rhombic prisms, but no distinct characters of it have been given.

Found at Schneeberg in Saxony.

d. RHOMBIC WHITE COBALT, No. 32.

Found at Hokambo in Sweden, having the bright lustre of arsenical cobalt, and the form and measurements of arsenical iron. No analysis or description has been given.

Sulpho-arseniuret of Cobalt and Iron.

a. GREY COBALT, No. 43.

Haüy, 4.225. Phil. 278. Haid. 2.455. Leon. 6.80.

Occurs in attached crystals and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the plane of the Cube, Octahedron, and Rhombic dodecahedron, indistinct. Fracture uneven. Hard. 5.5. Sp.gr. 6.466. Lustre metallic. Colour greyish-tin-white. Streak greyish-black.

Massive varieties, reticulated; amorphous. Structure granular, compact.

Found principally at Schneeberg in Saxony, and in Bohemia. Used in the manufacture of Smalt.

b. *Grey cobalt?* No. 114.

Brit.Min. tab. 472.

Is described as amorphous. Fracture uneven, like broken steel, and very brittle. Sp.gr. 5.5, 7.2. Lustre metallic. Colour rather dull steel-grey. Streak brighter.

Found at Dolcoath mine in Cornwall.

The white and grey ores of cobalt require a more precise examination than they have hitherto received, which will probably separate them into distinct species.

Cobalto-bismuthic Arsenic.

a. KERSTENITE, No. 33.

E.J.S. 6.355. Leon. 720 ?

Massive. Structure fibrous, imperfect radiated, rather porous. Sp.gr. 6.0, 6.7. Lustre nearly metallic. Colour between lead-grey and steel-grey.

Found at Schneeberg in Saxony.

Oxide of Cobalt and Manganese.

a. EARTHY COBALT. *Cobalt ochre*, No. 129.

Haüy, 4.230. Phil. 281. Haid. 3.78. Leon. 162.3, 238.9.

Occurs in botryoidal, stalactitic, and amorphous masses. Structure fine granular, earthy. Soft. Sp.gr. 2.2. Opaque. Colour bluish-black, brownish, and yellowish. Streak shining.

Found in Hessia, Thuringia, and other depositaries of the ores of cobalt.

It is not improbable that the brown and yellow varieties may upon further examination appear not to belong to one species.

Sulphate of Cobalt.

a. SULPHATE OF COBALT, No. 547.

Phil. 282. Haid. 3.145. Leon. 114.

Occurs in small globular, stalactitic, and amorphous masses, thinly investing other Minerals. Soft. Soluble in water. Translucent. Lustre vitreous, often dull externally. Colour pale rose-red.

Found among the mining heaps of old mines at Bieber, near Hanau, and in Salzburg.

Sulphuret of Cobalt.

a. SULPHURET OF COBALT, No. 75.

Phil. 280. Haid. 3.88. Leon. 653.

Occurs in imbedded amorphous masses. Structure fine granular, compact. Fracture uneven. Lustre metallic. Colour steel-grey, with a reddish tarnish. Streak grey.

Found at Riddarhittan in Sweden.

COMPTONITE, No. 340.

Phil. 201. Haid. 3.89. Leon. 193. 730.

Occurs in attached crystals in the cavities of fragments of an amygdaloidal rock at Vesuvius.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 91°. Cleavage parallel to both diagonals of the terminal planes. Fracture uneven. Hard. 5.0, 5.5. Transparent, translucent. Lustre vitreous. Colour white. Streak white.

Found at Vesuvius, and in a trap rock in Bohemia.

CONDRODITE. *Brucite. Maclureite*, No. 515.

Haüy, 2.476. Phil. 97. Haid. 3.87. Leon. 533.

Occurs in imbedded, rounded nodules of various sizes, generally small, the larger ones sometimes protruding into cavities in the matrix, and presenting crystalline forms not yet described.

Cleavage described as parallel to the lateral planes of a Rhombic prism of 124°. Fracture uneven. Hard 6.5. Sp.gr. 3.2, 3.5. Transparent, translucent. Lustre vitreous. Colour yellow to brown.

Found in Finland, and in several parts of North America. And it is probable, from the difference in appearance of different specimens, that the name has been given to two or more different substances.

COPPER.

Arseniate of Copper.

Right prismatic.

a. LINSENERZ. *Octahedral Arseniate*, No. 477.

Haüy, 3.509. Phil. 316. Haid. 2.160. Leon. 172.

Occurs in attached, obtuse, octahedral crystals.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 107° 5′. Levy. Cleavage parallel to the primary planes. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 2.926. Transparent, translucent. Lustre vitreous. Colour light blue and occasionally dull green. Streak pale blue or green.

Found in Cornwall near Redruth, and in Hungary.

b. OLIVENITE. *Olivenerz*, No. 478.

Haüy, 3.510. Phil. 319. Haid. 2.164. Leon. 168

Occurs crystallized and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 110° 30′. Levy. Cleavage parallel to the primary planes. Fracture uneven. Hard. 3.0. Sp.gr. 4.28. Transparent, translucent. Lustre vitreous, bright. Colour various shades of green, generally inclining to olive. Streak paler green.

Massive varieties, globular, reniform, nodular. Structure fibrous, occasionally granular, compact.

Found in Cornwall near Redruth, and near Alstonmoor in Cumberland.

c. EUCHROITE, No. 479.

Haid. 3.94. Leon. 173.

Occurs in attached or imbedded crystals.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 117° 20′. Cleavage parallel to M indistinct. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 3.39. Transparent, translucent. Lustre vitreous. Colour *emerald*-green. Streak lighter green.

Found at Libethen in Hungary.

Oblique prismatic.

a. TRIEDRAL *Arseniate* of Bournon, No. 480.

Phil. 318. Haid. 3.144. Leon. 170.

Occurs crystallized and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 95°. M,M′ = 56°. Cleavage parallel to P. Fracture indistinct. Hard. 2.5, 3.0. Sp.gr. 4.2. Transparent, translucent. Lustre vitreous. Colour dark blue to blackish-green. Streak paler green.

Massive varieties, reniform, amorphous, with a lamellar structure.

Found in Cornwall near Redruth.

Rhomboidal.

a. COPPER MICA, No. 481.

Haüy, 3.509. Phil. 317. Haid. 2.178. Leon. 171.
Occurs in attached crystals.
Primary form a Rhomboid. CRYST. fig. 106. P,P′= 69° 48′. Levy. Crystals usually tabular, thin. Occasionally in floriform groups. Cleavage distinct, perpendicular to the axis, less so parallel to P. Fracture uneven. Hard. 2.0. Sp.gr. 2.549. Transparent, translucent. Lustre vitreous. Colour emerald-green. Streak rather pale green.
Found in Cornwall near Redruth.

Not Crystallized.

a. ERINITE, No. 482.
E.J.S. 9.93.
Occurs in concentric layers, between which other arseniates are found. No crystals observable. The surface of the layers rough, the fracture uneven, with slightly resinous lustre. Hard. 4.5, 5.0. Sp.gr. 4.04. Slightly translucent. Colour emerald-green. Streak paler green.
Found near Limerick.

b. CONDURRITE, No. 483.
P.M. and An. 2.286.
Considered by Mr. Phillips to be an accidental deposit resulting from the decomposition of other ores containing copper and arsenic.
Amorphous. Fracture conchoidal. Scratched by glass. When cut by a knife a polished lead-grey surface is produced. Sp.gr. 5.20. Opaque. Surface of fracture very smooth. Colour brownish-black. Streak black.
Found in Condurrow Mine, near Camborne, Cornwall.

Arseniuret of Copper? No. 35.

P.M. and An 2. 287.
Metallic. Amorphous. Yields to the knife. Malleable. Colour tin-white.
Found in Condurrow mine, near Camborne, Cornwall, accompanying and coated by Condurrite.

Carbonate of Copper.

a. BLUE CARBONATE OF COPPER, No. 461.
Haüy, 4.3. Phil. 309. Haid. 2.167. Leon. 152.
Occurs crystallized and massive.
Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 91°30′, M,M′ = 98° 50′. Cleavage parallel to P, dull, and also to M, and both diagonals, and to *e.* CRYST. fig. 83. Fracture uneven. Structure fibrous, large or small, parallel or diverging, sometimes curved, and lamellar transversely to the direction of the fibres. Occasionally granular, sometimes earthy. Hard. 3.5, 4.0. Sp.gr. 3.83. Transparent, translucent. Lustre vitreous, bright. Colour various shades of blue. Streak paler blue.
Massive varieties, globular, botryoidal, reniform, stalactitic.
Found in fine crystals at Chessy, near Lyons in France, in Siberia, the Bannat, Cornwall, and many other places.

b. MALACHITE. *Green Carbonate of Copper*, No. 460.
Haüy, 3.488. Phil. 310. Haid. 2.175. Leon. 155.
Occurs crystallized and massive.
Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 112° 33′. M,M′ = 107° 16′. The crystals generally acicular, and too slender for measurement. Cleavage parallel to P and to the oblique diagonal of the terminal planes. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 4.0. Transparent, translucent. Lustre vitreous, bright. Colour various shades of green. Streak paler green.
Massive varieties, amorphous, or in tuberose, globular, reniform, botryoidal, and stalactitic shapes. Structure fibrous, the fibres sometimes so slender as to appear compact, and then producing a silky lustre, and yielding a conchoidal fracture.
Found in the same places, generally, as the blue carbonate.
Crystals of green carbonate sometimes occur under the forms of blue carbonate and of red oxide, from which they have been produced by some natural process in the mine. These are termed Epigene by Haüy.

c. ANHYDROUS CARBONATE OF COPPER, No. 463.
Phil. Tr. 1814, p. 45. An. 16. 39.
Occurs amorphous. Structure imperfectly foliated. Fracture small-conchoidal. Easily scratched with a knife. Sp.gr. 2.62. Colour dark blackish-brown. Streak reddish-brown.
Found in India, N.W. of Madras, accompanying Malachite.

Carbonate of Copper and Zinc.

a. KUPFERSCHAUM, No. 464.
Haid. 2.180. Leon. 756.
We believe that two or more different Minerals, presenting nearly the same external characters, have been included by different authors under this name.
The Mineral here alluded to consists of small, silky tufts or globules, composed of very thin radiating leaves or leafy fibres, without any appearance of crystalline form, or any observable cleavage or fracture. Colour bright bluish-green.
Found in the Bannat, and at Matlock in Derbyshire. Other localities are mentioned, but they possibly relate to some other Mineral.

Chloride of Copper.

a. ATACAMITE. *Muriate of Copper*, No. 66.
Haüy, 3.484. Phil. 313. Haid. 3.74. Leon. 212.
Occurs in attached crystals; as a green sand at Atacama in Peru; and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 100°. Cleavage parallel to P distinct, less so parallel to M. Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 4.4. Translucent to opaque. Lustre vitreous. Colour green, of various shades, but chiefly dark emerald-green. Streak lighter green.
Massive variety, reniform, with a fibrous structure.
Found principally at Remolinos in Chile.

Native Copper.

a. NATIVE COPPER, No. 8.
Haüy, 3.423. Phil. 296. Haid. 2.444. Leon. 710.
Occurs in variously branched and aggregated crystals, in plates and massive. Primary form a Cube. CRYST. fig. 56. No cleavage. Fracture hackly. Hard. 2.5, 3.0. Sp.gr. 7.7, 8.5. Lustre metallic. Colour red, frequently much tarnished. Streak shining.
Massive varieties, generally amorphous.
Found in Cornwall and in most other Countries, in veins, and occasionally in beds.

Oxide of Copper.

a. RED OXIDE OF COPPER. *Oxydulous Copper.* When earthy, *Tile-ore*, No. 131.
Haüy, 3.462. Phil. 306. Haid. 2.381. Leon. 566 9.
Occurs in attached crystals, and massive, occasionally in thin plates and fibrous.
Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the regular octahedron.

Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 6.0. Transparent, translucent. Lustre adamantine, approaching sometimes to metallic. Colour red of several shades. Streak dull red.

Massive varieties, amorphous. Structure crystalline and amorphous, or botryoidal, with an earthy structure.

Found in most copper mines accompanying other ones of this metal.

Phosphate of Copper.

Right prismatic.

a. LIBETHENITE, No. 495.

Haüy, 3.519. Phil. 314. Haid. 2.166. Leon. 143.

Occurs in small attached octahedral crystals.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 109° 30′. Cleavage parallel to P, distinct; less so parallel to M. Fracture uneven. Hard. 4.0. Sp.gr. 3.6. Transparent, translucent. Lustre resinous. Colour dark green. Streak green.

Found principally at Libethen in Hungary.

Hydrous Phosphate of Copper.

a. RHENITE, No. 496.

Haüy, 3.519. Phil. 315. Haid. 2.173. Leon. 143.

Occurs in attached crystals and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 97° 30′. M,M′ = 37° 30′. Cleavage indistinct, parallel to the horizontal diagonal. Fracture uneven. Hard. 4.5, 5.0. Sp.gr. 4.2. Translucent, opaque. Lustre vitreous. Colour various shades of green, frequently blackish. Streak pale green.

Massive varieties, botryoidal and amorphous. Structure fibrous.

Found near Rheinbreitbach on the Rhine.

Seleniuret of Copper.

a. SELENIURET OF COPPER, No. 53.

Haüy, 3.469. Phil. 304. Haid. 3.150. Leon. 394.

Occurs massive and in thin plates in carbonate of lime at Smaland, Sweden. Soft. Malleable. Lustre metallic. Colour silver-white. Streak shining.

Silicate of Copper.

a. DIOPTASE. *Emerald Copper*, No. 178.

Haüy, 3.477. Phil. 312. Haid. 2.171. Leon. 220.

Occurs in attached crystals.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 126° 17′. Cleavage parallel to P. Fracture uneven. Hard. 5.0. Sp.gr. 3.278. Transparent, translucent. Lustre vitreous. Colour emerald to blackish-green. Streak green.

Found in the Kirghese Steppes, and according to Phillips, at Risbanya in the Bannat.

b. CHRYSOCOLLA. *Copper-green*, No. 179.

Haüy, 3.471. Phil. 312. Haid. 2.158. Leon. 219.

Occurs massive.

No proper crystalline form or cleavage yet observed, but occurring in Siberia and Cornwall in epigene or pseudomorphous crystals, of some of the forms of arseniate, blue carbonate, and red oxide of copper. Hard. 2.0, 3.0. Sp.gr. 2.031. Translucent. Lustre vitreo-resinous. Colour bluish and blackish-green. Streak green.

Several localities are named of this substance, but it is probable that they relate to very different Minerals, some of which appear to be only quartz or calcedony, coloured by carbonate of copper.

Sulphate of Copper.

a. *Soluble*, No. 534.

Haüy, 3.523. Phil. 313. Haid. 2.44. Leon. 111.

Occurs in stalactitic, fibrous, and earthy masses, seldom in crystals.

Primary form an Oblique rhombic prism. CRYST. fig. 95. P,M = 109° 32′. P,T = 128° 27′. M,T = 149° 2′. Cleavage indistinct, parallel to T and M. Fracture conchoidal. Hard. 2.5. Sp.gr. 2.213. Transparent, translucent. Lustre vitreous. Colour bright blue. Streak white.

Found in several copper mines in this and other Countries.

b. BROCHANTITE? No. 515.

An. N.S. 8.241. Haid. 3.81. Leon. 724.

Occurs in minute, thin, rectangular crystals. Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 111° 20′. Cleavage and fracture uncertain. Hard. 3.5, 4.0. Transparent. Lustre vitreous. Colour emerald-green and blackish-green.

Found at Catherinenburg in Siberia, covering mamellated green carbonate of copper.

c. KONIGINE? No. 546.

An. N.S. 11.194.

Primary form a Right rhombic prism, CRYST. fig. 71. M,M′ = 105°. Cleavage perpendicular to axis of prism. Hard. 3.5, 4.0. Translucent Lustre vitreous. Colour emerald-green and blackish-green.

Found at Catherinenburg in Siberia.

Sulphuret of Copper.

a. VITREOUS COPPER, No. 77.

Haüy, 3.454. Phil. 297. Haid. 3.8. Leon. 566, 640.

Occurs in attached hexagonal prisms and massive. Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 71° 30′ nearly. Cleavage parallel to the hexagonal pyramids corresponding to the primary plane. Fracture conchoidal. Hard. 2.5, 3.0. Sp.gr. 5.7. Lustre metallic. Colour lead-grey, frequently tarnished. Streak shining.

Massive varieties, amorphous; structure granular to compact.

Found in Cornwall, finely crystallized, and in most other depositories of copper ore.

Sulphuret of Copper, Iron, &c.

A. FAHLORE. *Grey Copper*, No. 78.

a. *Arsenical.*

Haüy, 3.441. Phil. 300. Haid. 3.1. Leon. 648.

Occurs in attached and imbedded crystals, and massive. Primary form a Cube. CRYST. fig. 56. Predominating form the regular tetrahedron. Cleavage parallel to the planes of the tetrahedron, very indistinct. Fracture conchoidal. Hard. 3.0, 4.0. Sp.gr. 4.8, 5.1. Opaque. Lustre metallic. Colour steel-grey. Streak nearly the same.

Massive varieties, amorphous; structure granular to compact, and sometimes earthy.

Is found accompanying most other copper ores.

b. *Antimonial.*

Differs from the arsenical chiefly in colour, which is much darker. It is also more frequently tarnished on the surface, presenting a remarkable contrast to the relative characters of antimony and arsenic in their native state. The fractured surfaces of antimony retaining their metallic brightness after exposure to the air, while those of arsenic speedily become dull and black.

B. TENNANTITE. No. 79.

Phil. 304. Haid. 3.161. Leon. 604.

Occurs in attached crystals.

Primary form a Cube. CRYST. fig. 56. Cleavage

parallel to the planes of the regular octahedron. Fracture uneven. Hard. exceeding 3.0. Sp.gr. 4.375. Lustre metallic. Colour lead-grey, frequently tarnished on the surface. Streak reddish-grey.

Found in several of the copper mines in Cornwall.

b. PURPLE COPPER. *Buntkupfererz*, No. 80.

Haüy, 3.436. Phil. 299. Haid. 2.467. Leon. 643.

Occurs in attached crystals and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the regular octahedron, indistinct. Fracture uneven. Hard. 3.0. Sp.gr. 5.0. Lustre metallic. Colour purplish and reddish-brown, generally tarnished on the surface. Streak greyish-black.

Massive variety, amorphous. Structure compact.

Found in most copper mines.

A variety of this substance occurs in Cornwall, in the form of thin hexagonal prisms, which are probably pseudomorphous.

Sulphuret of Copper and Iron.

a. COPPER PYRITES. *Yellow Copper*, No. 81.

Haüy, 3.432. Phil. 302. Haid. 2.469. Leon. 644.

Occurs in attached and imbedded crystals, and massive.

Primary form a Square prism. CRYST. fig. 65. $P,e = 117° 15'$. Cleavage parallel to e, fig. 68. Fracture conchoidal. Hard. 3.5, 4.0. Sp.gr. 4.17, 4.3. Lustre metallic. Colour brass-yellow, frequently with a violet and purple tarnish on the surface. Streak greenish-black.

Massive varieties, globular, botryoidal, reniform, stalactitic, and amorphous.

Found in most mines where copper is produced.

b. KUPFERINDIG, No. 83.

Haid. 3.118. Leon. 755.

Occurs in imbedded spheroidal masses, and in flat layers, having an uneven fracture, and a fine granular or earthy structure. Soft. Sp.gr. 3.8. Opaque. Lustre dull resinous. Colour dark blue. Streak shining.

Found in Salzburg and in Thuringia

Silicate and Sulphate of Copper.

a. VELVET COPPER, No. 567.

Haid. 3.168.

Occurs in very short capillary crystals coating the surface of the matrix, and presenting a velvety appearance. Translucent. Lustre pearly. Colour bright blue

Found at Moldawa in the Bannat, and consists of silica, sulphuric acid, and oxides of copper and zinc.

Composition unknown.

a. PELOKONITE, No. 569.

E.N.P.J. 12.134.

Occurs amorphous. No cleavage. Fracture conchoidal. Hard. 3.0. Sp.gr. 2.51, 2.57. Opaque. Lustre vitreous, nearly dull. Colour bluish-black. Streak liver-brown.

Found in the Tierra Amarilla and Remolinos in Chili, accompanying green carbonate of copper. Soluble in muriatic acid, the solution yellowish-green. Not analyzed.

CRYOLITE, No. 514.

Haüy, 2.157. Phil. 197. Haid. 2.66. Leon. 570.

Occurs in single or aggregated crystalline masses.

Primary form not observed. Cleavage parallel to the terminal and lateral planes of a rectangular prism. Fracture uneven. Hard. 2.5, 3.0. Sp gr. 2.963. Translucent, and becomes more transparent after immersion in water. Lustre vitreous, rather pearly on one surface. Colour white, or reddish, or yellowish-brown. Streak white.

Found at Arksut-fiord, West Greenland.

DAVYNE, No. 341.

E.J.S. 7.326. Leon. 433.

Occurs in attached regular hexagonal prismatic crystals with the terminal edges truncated.

Primary form a Rhomboid. CRYST. fig. 106. $P,P' = 112° 16'$. Corresponding nearly, if not exactly, with Nepheline. Cleavage parallel to the planes of the hexagonal prism, distinct. Fracture conchoidal. Hard. 5.0, 5.5. Sp.gr. 2.4. Transparent. Lustre vitreous, pearly upon the cleavage planes. Colour white, sometimes yellowish-brown. Streak white.

Found in cavities, in some of the masses ejected from Vesuvius.

DESMINE, No. 342.

Occurs in small silky tufts accompanying Spinellane from the extinct volcanoes of the Rhine.

DICHROITE. *Iolite. Peliome. Steinheilite*, No. 305.

Haüy, 3.1. Phil. 93. Haid. 2.319. Leon. 466.

Occurs in imbedded crystals, and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M' nearly 120°. Cleavage parallel to the lateral planes. Fracture conchoidal. Hard. 7.0, 7.5. Sp.gr. 2.583. Transparent, translucent. Lustre vitreous. Colour blue in the direction of the axis, and yellowish-grey perpendicular to it; sometimes dull yellowish in both directions. Streak white.

Massive varieties, amorphous. Structure indistinctly granular.

Found in Spain, in Bavaria, in Finland, and other localities.

DIPYRE. *Leucolite*, No. 343.

Haüy, 2.596. Phil. 45. Haid. 2 264. Leon. 475.

Occurs in small imbedded crystals.

Primary form not determined. Fracture conchoidal. Hard. 5.0, 5.5. Sp.gr. 2.63. Opaque. Lustre internally vitreous. Colour greyish and reddish-white.

Found in the Western Pyrenees.

DISLUITE, No. 344.

Occurs at Franklin, New Jersey, North America, in regular octahedral crystals imbedded in carbonate of lime.

Colour yellowish-brown. No published description or analysis. Possibly brown Spinelle.

DOMITE, No. 345.

Phil. 203.

Occurs in white, greyish, or yellowish, earthy or pulverulent, amorphous, masses, at Puy de Dome, in Auvergne.

EDINGTONITE, No. 221.

E.J.S. 3.316. Leon. 731.

Occurs in attached crystals in the cavities of Thomsonite.

Primary form, according to Haidinger, a Square prism. CRYST. fig. 65. Cleavage parallel to the lateral planes. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 2.71. Translucent. Lustre vitreous. Colour greyish-white. Streak white

Found in the neighbourhood of Dumbarton, Scotland.

ELAOLITE. *Fettstein. Lythrodes. Sodaite* No. 238.

Haüy, 4.505. Phil. 136. Haid. 3.93. Leon. 468.
Occurs in amorphous masses, with cleavages parallel to the lateral planes, and both the diagonals of a Rhombic prism of 112°. Fracture conchoidal. Hard. 5.5, 6.0. Sp.gr. 2.55, 2.62. Translucent. Lustre vitreo-resinous, sometimes fatty, occasionally opalescent. Colour greenish or bluish-grey, or greyish or brownish-red.
Found in Norway imbedded in Syenite.

EMERALD. *Beryl. Aquamarine*, No. 322.
Hauy, 2.504. Phil. 102. Haid. 2.316. Leon. 391.
Occurs in attached and imbedded crystals and massive.
Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 104° 28′. Cleavage parallel to all the planes of a regular hexagonal prism, the form it generally assumes. Fracture uneven. Hard. 7.5, 8.0. Sp.gr. 2.68, 2.732. Transparent, translucent. Lustre vitreous. Colour various shades of green, blue, and yellow. Streak white.
Massive varieties, amorphous, structure large granular, or globular with a fibrous structure.
Found in Columbia, Peru, Brazil, North America, Siberia, and in several parts of Europe.

EPIDOTE. *Pistazite. Thallite*, No. 289.
Haüy, 2.568. Phil. 41. Haid. 2.282. Leon. 476.
Occurs in attached and imbedded crystals, massive and granular.
Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 103° 10′. M,M′ = 63° 25′. Cleavage parallel to P and *h*, fig. 91. Fracture uneven. Hard. 6.0, 7.0. Sp.gr. 3.425, 3.45. Transparent to opaque. Lustre vitreous. Colour various shades of green, greenish-grey, brownish-yellow, and blackish-red. Streak greyish-white.
Massive varieties, amorphous. Structure granular, compact, fibrous. Occasionally arenaceous.
Found in many parts of Europe and America, and in the East Indies.
Thulite and Withamite have been referred to this species.

EPISTILBITE, No. 214.
E.J.S. 4.286. Leon. 735.
Occurs in crystals attached to a mass of the same substance.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 135° 10′. Cleavage parallel to the short diagonal of the prism. Fracture uneven. Hard. 4.5. Sp.gr. 2.25. Transparent, translucent. Lustre vitreous. Colour white. Streak white.
Found in Iceland and the Faroe Islands.

ERLANITE, No. 243.
An. N.S. 8.389. Leon. 736.
Occurs massive and amorphous, forming a bed of 100 fathoms in thickness. Structure granular, compact. Fracture foliated, splintery. Hard. 5.5. Sp.gr. 3.0, 3.1. Opaque. Lustre very feeble. Colour greenish-grey. Streak white, shining.
Found in the Saxon Erzgebirge, near Erla
Used as a flux by iron smelters.

EUCLASE, No. 323.
Haüy, 2.528. Phil. 101. Haid. 2.313. Leon. 395.
Occurs in detached crystals in alluvial ground in Brazil.
Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 118° 46′. M,M′ = 114° 50′. Cleavage parallel to the terminal plane, and horizontal diagonal, indistinct, but very distinct parallel to the oblique diagonal. Fracture uneven. Hard. 7.5. Sp.gr. 3.098. Transparent. Lustre vitreous. Colour pale bluish-green, blue, and white. Streak white.

EUDYALITE, No. 329.
Phil. 122. Haid. 3.96. E.P.J. 12.81. Leon. 390.
Occurs in imbedded crystals and massive.
Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 73° 40′. Cleavage parallel to *a*, fig. 107. and to *p*, fig. 121. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.9. Faintly translucent, opaque. Lustre vitreous, sometimes dull. Colour brownish-red. Streak white.
Massive varieties, imbedded and amorphous.
Found in Greenland.

FAHLUNITE. *Tricklasite*, No. 265.
Haüy, 3.140. Phil. 56. Haid. 3.97. Leon. 737.
Occurs in imbedded, regular, hexagonal prisms, and in amorphous masses. Cleavage perpendicular to the axis of the prism. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.66. Nearly opaque. Colour blackish, yellowish, and greenish-brown. Streak greyish-white.
Found at Fahlun in Sweden.
This has been described as a Right rhombic prism of 109° 28′, and it is said to be cleavable parallel to the lateral planes.

FELSPAR. *Orthose*, No. 226.
Haüy, 3.79. Phil. 113. Haid. 2.251. Leon. 424.
Occurs crystallized and massive.
Primary form an Oblique rhombic prism. P,M = 112° 35′. M,M′ = 118° 58′. Cleavage parallel to the terminal plane and the oblique diagonal, distinct; less so parallel to M and M′. Fracture conchoidal, uneven. Hard. 6.0. Sp.gr. 2.5, 2.6. Transparent, translucent. Lustre vitreous. Colour white, grey, green, red, of different shades. Streak greyish-white.
Massive varieties, amorphous. Structure granular, compact. Sometimes in imbedded globular concretions. But it will probably be found that several distinct Minerals have been classed as compact felspar.
Found in all parts of the World.

FORSTERITE, No. 346.
An. N.S. 7.59. Haid. 3.102. Leon. 739.
Occurs in attached, small, brilliant crystals.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 128° 54′. Cleavage parallel to P. Harder than quartz. Translucent. Lustre vitreous. Colour white.
From Vesuvius, accompanied by Pleonaste and Pyroxene.

FREISLEBEN, No. 347.
Lucas, 2.216.
Is described as having a foliated fracture. Hard. about 3.0. Considerable lustre. Colour blue, sometimes greyish. Soft to the touch. Insoluble in water.
No locality or analysis given.

FUSCITE, No. 348.
Phil. 204. Leon. 474.
Is said by Phillips to be a Rhombic prism of 87° and 93°; is considered by Haidinger to be Pyroxene, and by Leonhard to be Scapolite. It is, therefore, a doubtful species.

Found near Arendahl in Norway.

GABRONITE, No. 232.

Phil. 139.

Occurs crystallized and massive. Primary form a Square prism. CRYST. fig. 65. Cleavage parallel to the lateral planes, indistinct. Fracture uneven. Hard. about 5.0. Sp.gr. 2.9. Opaque. Dull. Colour bluish or greenish-grey, red.

Found only in Norway.

GARNET. Precious, *Almandine*. Black, *Melanite*, *Pyreneite*. Greenish-yellow, *Grossularia*. Yellow, crystallized, *Topazolite*; granular, *Succinite*. Brownish-yellow, granular, *Colophonite*. Greenish, compact, *Allochroite*. Red, *Pyrope*, *Carbuncle*, Reddish-brown, *Essonite*, *Cinnamon-stone*, *Romanzovite*. Magnesian, *Rothoffite*, No. 294—301.

Probably some of these are distinct species, although their crystals are similar in form.

Haüy, 2.213. Phil. 26. Haid. 2.359. Leon. 487.

Occurs in attached and imbedded crystals of the form of rhombic dodecahedrons, granular and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the rhombic dodecahedron, very indistinct. Fracture uneven. Hard. 6.5, 7,5. Sp gr. 3.6, 4.2. Transparent, translucent, rarely opaque. Lustre vitreous, resinous. Colour various shades and combinations of green, yellow, red, brown, black, white. Streak white.

Massive varieties, amorphous, structure granular, compact.

Found in most of the mountainous parts of the World.

GEHLENITE, No. 303.

Haüy, 2.557. Phil. 35. Haid. 3.102. Leon. 212.

Occurs in imbedded and massive aggregations of rectangular, or slightly rhombic crystals.

Primary form uncertain. Cleavage parallel to the planes of a rectangular or rhombic prism. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 3.029. Slightly translucent, opaque. Lustre slightly vitreous, resinous. Colour grey, sometimes yellowish or greenish.

Found only in the valley of Fassa in the Tyrol.

GIESECKITE, No. 264.

Phil. 113. Haid. 3.104. Leon. 461. 464, 465.

Occurs in imbedded crystals in the form of hexagonal prisms.

Structure of the crystals granular. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 2.832. Opaque. Lustre slightly resinous. Colour brownish-grey and greenish. Streak white.

Found in Greenland by Sir Charles Giesecké.

GIGANTOLITE, No. 349.

A name given by Nordenskiold, on account of the size of the crystals, to a Mineral occurring in Finland, but first found at Schneeberg in Saxony, and then called Pinite. The Saxon specimens are decomposed, soft, and dull red. The Finland Mineral is not decomposed, and is dull dark green. Both varieties present the form of imperfect hexagonal prisms, and may be split into thin plates. The same substance has been found in North America, and named Phyllite.

GLAUCOLITE, No. 244.

P.M. and An. 2.463. Leon. 742.

Occurs massive. Structure crystalline. Cleavage parallel to the planes of a Rhombic prism, of about 107° or 143° 30′, indistinct. Fracture uneven. Hard. 5.0, 6.0. Sp gr. 2.7, 3.2. Translucent. Lustre vitreous. Colour lavender-blue, green. Streak lighter.

Found near the lake Baikal in Siberia.

This Mineral affords an instance of the disadvantage of significant names, as at least three different substances have been so called, merely on account of their colour, one of which, from Norway, has a cleavage parallel to the planes of the rhombic dodecahedron, and another has no apparent cleavage.

GMELINITE. *Hydrolite*, De Drée, No. 211.

Haüy, 3.177. Haid. 3.104. Leon. 742.

Occurs in attached crystals of the form of hexagonal prisms, lining cavities in trap rocks.

Primary form a Rhomboid. CRYST. fig. 106. Cleavage parallel to the primary planes. Fracture uneven. Hard. 4.5. Sp.gr. 2.05. Translucent. Lustre vitreous. Colour white, and pale dull yellow and red. Streak white.

Found in the Vicenti, in Ireland, and in North America.

GOLD.

a. NATIVE GOLD, No. 17.

Haüy, 3.235. Phil. 322. Haid. 2.436. Leon. 707.

Occurs only in a metallic state, crystallized, and massive.

Primary form a Cube. CRYST. fig. 56. No cleavage. Fracture hackly. Hard. 2.5, 3.0. Sp.gr. 14.857. Opaque. Lustre metallic. Colour yellow, of several shades. Streak shining.

Found in North America, Mexico, Brazil, Peru, and other parts of South America, and in several parts of Europe, Asia. and Africa.

Native Gold is usually alloyed with a small quantity of silver. When the proportion is considerable the compound passes under the name of

b. ELECTRUM, No. 18.

GREEN EARTH, *Talc Zographique*, No. 257.

Haüy, 2.493. Phil. 117. Haid. 2.193. Leon. 189.

Occurs massive, imbedded in or lining the cavities of trap rocks. Fracture earthy. Hard. 1.0, 1.5. Sp gr. 2.631. Opaque. Dull. Colour greyish, bluish, blackish-green. Streak shining.

Found in the Faro Islands, and in several parts of Europe, particularly near Verona, and generally wherever amygdaloidal rocks occur.

Several apparently different substances are so named on account of their colour and earthy fracture. Crystals of a green earthy substance of the form of Pyroxene are occasionally found in trap rocks.

HARMOTOME. *Andreolite*. *Ercinite*, No. 220.

Haüy 3.142. Phil. 56. Haid. 2.229. Leon. 196.

Occurs in attached crystals, generally intersecting each other lengthwise.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′= 110°; Levy. Cleavage parallel to the primary planes, and to both the diagonals of the prism. Fracture uneven. Hard. 4.5. Sp.gr. 2.35, 2.39. Transparent, translucent. Lustre vitreous, sometimes pearly. Colour greyish, yellowish, reddish-white. Streak white.

Found in Scotland, and in several places on the Continent of Europe.

The crossed crystals most commonly met with are

from Andreasberg, and the simple ones from Strontian in Scotland.

HARRINGTONITE, No. 350.

A white substance so named from Ireland. It occurs in thin tabular masses, with a fine granular structure, and may possibly be only a variety of some known Mineral.

HAÜYNE. *Latialite*, No. 565.

Haüy, 2.335. Phil. 374. Haid. 3.107. Leon. 459.

Occurs in attached dodecahedral crystals, granular, and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the diagonal planes of the cube, indistinct. Fracture uneven. Hard. 5.5, 6.0. Sp gr. 2.68. Transparent to opaque. Lustre vitreous. Colour blue, sometimes greenish, white. Streak white.

Massive varieties, amorphous, structure granular, compact.

Found in the cavities of ancient lavas, and in the fragments of rocks ejected from Vesuvius.

HEDENBERGITE, No. 351.

Haüy, 4.495. Phil. 66. Leon. 506.

Is said by Phillips to measure the same as *Amphibole;* by Levy to be *Pyroxene;* by Berzelius to cleave into *obtuse rhomboids*, similar to that of *carbonate of lime;* and by Haüy, into *octagonal prisms* with a base oblique to the axis. It is uncertain, therefore, to what Mineral the published descriptions really apply.

HELVIN, No. 302.

Haüy, 2.333. Phil. 244. Haid. 2.357. Leon. 462.

Occurs in attached and imbedded tetrahedral or octahedral crystals.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the regular octahedron, indistinct. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 3.166. Translucent. Lustre vitreo-resinous. Colour dull yellow, sometimes brownish. Streak white.

Found at Schwarzenberg in Saxony.

HERDERITE, No. 352.

P.M. and An. 4 1.

Occurs in imbedded crystals.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 115° 53′. Cleavage parallel to the lateral planes, and to the long diagonal of the prism. Fracture small conchoidal. Hard. 5.0. Sp gr. 2.985. Nearly transparent. Lustre vitreous, slightly inclined to resinous. Colour yellowish and greyish-white. Streak white.

Found imbedded in Fluor at Ehrenfriedersdorf in Saxony.

HERSCHELITE, No. 353.

An. N.S. 10.361. Leon. 745.

Occurs in attached hexagonal crystals in the cavities of granular olivine.

Primary form a Rhomboid. CRYST. fig. 106. P,*a* about 132°. No perceptible cleavage. Fracture conchoidal. Hard. about 4.0. Sp.gr. 2 11. Translucent. Opaque. Colour white.

Found at Aci Reale in Sicily.

HEULANDITE. *Haydenite*, No. 215.

Haüy, 3.155. Phil. 38. Haid. 2.242. Leon. 745.

Occurs in attached crystals and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 108° 1′. M,M′ = 97° 39′. Cleavage parallel to the oblique diagonal of the prism, very distinct. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 2.2. Transparent, translucent. Lustre vitreous, on the cleavage planes pearly. Colour white, grey, yellow, red, brown. Streak white.

Massive varieties, granular.

Found principally in Iceland and the Faroe Islands, and generally lining cavities in trap rocks.

HISINGERITE, No. 172.

Phil. 204. Haid. 3.108. Leon. 212, 746.

Occurs massive, with a distinct cleavage in only one direction, and an earthy fracture. Soft. Sp.gr. 3.045. Opaque. Colour black. Streak greenish-grey.

Found in Svärta Parish, Sudermanland.

HUMITE, No. 354.

Bour. Cat. 52. Phil. 205. Haid. 3.110. Leon. 747.

Occurs in attached crystals.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 120°. Cleavage parallel to M and M′ distinct and bright. Fracture uneven. Hard. 6.5, 7.0. Transparent, translucent. Lustre vitreous. Colour brownish-yellow and light reddish-brown. Streak white.

Found on Monte Somma.

HYALOSIDERITE, No. 284.

Haid. 3.111. Leon. 533.

Occurs in imbedded crystals in a brown basaltic amygdaloidal rock.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 105°; W.P. Cleavage parallel to P. Fracture uneven, Hard. 5.5. Sp.gr. 2.875. Translucent, opaque. Lustre vitreous, superficially metallic. Colour reddish-brown. Streak light brown.

Found at Kaiserstuhl in Brisgaw.

The form and measurements of this Mineral agree very nearly with those of Olivine.

HYPERSTHENE. *Diallage metalloide*, var. *Labrador Hornblende*. *Paulite*, No. 285.

Haüy, 2.417. Phil. 70. Haid. 2.209. Leon. 516.

Occurs in crystalline masses, sometimes presenting parts of the natural surfaces of crystals. Cleavage parallel to the lateral planes of a rhombic prism of 93° 30′, and to both diagonals. Fracture uneven. Hard. 6.0. Sp.gr. 3.389. Opaque. Lustre metallic in one direction, on the cross fracture, vitreous. Colour on the metallic looking surface reddish, in other directions greyish or greenish-black. Streak greenish-grey.

Massive varieties, amorphous.

Found at Labrador, and in the Island of St. Paul.

This and the Bronzite and Schiller spar have the same cleavages and measurements.

JADE. *Igida*, its Indian name. *Axe stone*. *Beilstein*. *Nephrite?* *Saussurite?* No. 306.

Haüy, 4.498. Phil. 134. Haid. 3.149. Leon. 422.

There is much uncertainty and confusion in the published description of Jade, Nephrite, and Saussurite; and it is not apparent what the Mineral is to which the name Igida has been applied in India. The Axe stone of the South Sea Islands appears to be a compact amianthus, or a serpentine enveloping a considerable quantity of amianthus. Werner's Jade or Beilstein is a brittle, yellowish-brown, fibrous Mineral. It is probable that the Chinese Jade is the substance which is also named Yu, and is believed to be Prehnite.

a. NEPHRITE, No. 307. This has been described as follows.

Haüy, 4.498. Phil. 134. Haid. 3.131. Leon. 764.

Occurs massive. Structure *fibrous*, compact. Fracture splintery. Hard. 7.0. Sp.gr. 2.9, 3.02. Translucent, opaque. Colour green of several shades. Very tough.

Found in China, Egypt, and the Islands in the South Seas, where it is cut by the natives into various forms.

b. SAUSSURITE, No. 308. This, which has been called by Haüy *Felspath tenace*, has also received the names *Jade*, *Axe stone*, &c. as synonyms, and is described as follows.

Haüy, 3.95. Phil. 135. Haid. 3.148. Leon. 422.

Occurs massive. Structure *foliated*, granular. Cleavage parallel to the planes of a Rhombic prism of about 124°; Haid. Fracture splintery. Hard. 5.5. Sp.gr. 2.25, 3.35. Nearly opaque. Lustre pearly. Colour greenish and greyish-white. Streak white.

Found in Corsica, Stiria, and some other places.

A more precise examination of these Minerals, and more distinct descriptions and analyses are necessary to a correct separation of the several varieties into more definite species. Specimens occur in Mineral cabinets under some or all of these names, which do not agree with any of the published descriptions.

IBERITE, No. 355.

An. 3.152.

Occurs in attached slender, four-sided prisms, with terminal faces obliquely truncated, and massive with a radiated structure.

Primary form not sufficiently described, and no measurements given. Cleavage parallel to the axis of the prism in two directions. Fracture uneven. Very soft. Translucent on the edges of the crystals. External lustre nearly dull, internal vitreous. Colour white. Adheres slightly to the tongue.

Found near Teflis in Georgia.

Is perhaps Laumonite, or one of the already known members of the family of Zeolites, in a state of partial decomposition.

IDOCRASE. *Vesuvian. Wiluite. Egeran.* Red, *Frugardite.* Greenish-yellow, *Loboite.* Blue, *Cyprine.* No. 291 to 293.

Haüy, 2.544. Phil. 33. Haid. 2.354. Leon. 483, 484.

Occurs in attached and imbedded crystals, and massive.

Primary form a Square prism. CRYST. fig. 65. Cleavage parallel to the primary planes, distinct, and less so parallel to the diagonals of the prism. Fracture uneven. Hard. 6 5. Sp.gr. 3.08, 3.4. Transparent, translucent. Lustre vitreo-resinous. Colour several shades of grey, blue, green, yellow, brown, black. Streak white.

Massive varieties, amorphous. Structure fibrous, granular, compact.

Found originally in the neighbourhood of Vesuvius, and since in many parts of Europe, and in Asia and America.

JEFFERSONITE, No. 273.

Haid. 3.115. Leon. 505, 506.

Has the form, measurements, and most other characters of Pyroxene.

Found near Sparta, New Jersey, North America.

ILMENITE, No. 356.

P.M. and An. 10.187. E.P J. N.S. 3.187, 386.

Occurs in imbedded crystals in Cleavelandite.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 136° 30′. No cleavage observed. Fracture uneven. Hard. 5.0. Sp.gr. 5.43. Opaque. Lustre vitreous. Colour black.

Found near Lake Ilmen in Siberia.

INDIANITE, No. 315.

Phil. 44. Haid. 3.113. Leon. 748.

Occurs in granular masses. Part of a fragment at the British Museum having afforded a measurement of 95° 15′ on cleavage planes. Hard. 5.0, 5.5 Sp.gr. 2.74. Bournon. Translucent. Colour nearly white.

Found in the Carnatic in India.

IRIDIUM.

a. OSMIURET OF IRIDIUM, No. 16.

Haüy, 3.234. Phil. 326. Haid. 3.114. Leon. 701.

Occurs in loose hexagonal crystals, and flattened grains, accompanying native platina.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ not ascertained. Cleavage perpendicular to the axis, very distinct. Hard. 4.5, 5.0. Sp.gr. 19.5. Opaque. Lustre metallic. Colour pale steel-grey.

Found in South America and in the Uralian mountains.

IRON.

Aluminate of Iron?

a. SKORIAN, No. 149.

Breit. 88.

Occurs in amorphous masses, resembling a slag or scoria.

Primary form apparently a Rhombic prism. Cleavage uneven. Fracture conchoidal, uneven. Hard. 8.0, 8.5. Sp.gr. 3.7, 3.8. Lustre vitreous. Colour black.

Found at Bischoffstein in Bavaria and at Schandau in Saxony.

Cubic Arseniate of Iron.

a. PHARMAKOSIDERIT, No. 469.

Haüy 4.135. Phil. 211. Haid. 2.162. Leon. 165.

Occurs in attached crystals, and sometimes massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the primary planes, indistinct. Fracture uneven. Hard. 2.5. Sp.gr. 3.0. Transparent, translucent, opaque. Lustre vitreous. Colour green of several shades, yellowish-red, yellowish and greenish-brown. Streak a paler colour.

Massive variety, amorphous, structure granular.

Found principally in Cornwall, also at St. Leonhard in France, at Schwartzenberg in Saxony, and at Franklin, North America.

Rhombic Arseniate of Iron.

a. SKORODITE. *Martial Arseniate of Copper* of Bournon, No. 468.

Phil. 320, 321. Haid. 3.149. Leon. 166.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′= 120° 10′. Phil. Cleavage parallel to the primary planes, indistinct. Fracture uneven. Hard. 3.5, 4 0. Sp.gr. 3.16, 3.2. Transparent, translucent, opaque. Lustre vitreous, brighter on the natural than the fractured surfaces. Colour bluish and blackish-green, brown, black. Streak white.

Massive varieties, globular, structure fibrous, radiating.

Found in Cornwall, Saxony, Carinthia, and in more perfect crystals in Brazil.

Berzelius seems to consider the variety from Brazil as a distinct species, but as it agrees in measurement with the others, it is probable that the analysis of more perfect specimens would lead to a different conclusion.

Arseniate of Iron?

a. Pittizite. *Iron pitch ore? Iron sinter?* No. 470.

Phil. 236. Haid. 3.115. Leon. 128.

Occurs in reniform and stalactitic masses. Structure compact. Fracture conchoidal. Soft. Sp.gr. 2.4. Translucent, opaque. Lustre vitreous. Colour brown of different shades.

Found in Saxony and Silesia.

An uncertain species, and probably comprehending several distinct Minerals, as specimens have been received in this Country under these names, differing from each other in all their physical characters.

b. Arsenite of Iron? No. 471.

Brit. Min. 5 275.

Described by Gregor as massive, compact to earthy. Lustre dull waxy. Colour dull bluish-olive-green.

Found in Cornwall.

Carbonate of Iron.

a. Carbonate of Iron. *Brown Spar. Sphathose Iron. Sphdrosederit*, when botryoidal or globular, No. 452.

Haüy, 4.113. Phil. 236. Haid. 2.102. Leon. 296,7.

Occurs in attached crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106. P,P′ = 107°. Cleavage parallel to the primary planes, distinct. Fracture imperfect conchoidal. Hard. 3.5, 4.5. Sp.gr. 3.6, 3.829. Transparent, translucent, opaque. Lustre vitreous, inclining to pearly. Colour white, yellowish, and greenish-grey, yellow, red, and brown of different shades.

Massive varieties, tabular. Structure fibrous, the direction of the fibres nearly perpendicular to the flat surfaces; botryoidal and globular, structure fibrous, diverging; amorphous structure, foliated, granular, compact.

Found in Cornwall, Scotland, and Ireland, and in many metalliferous veins in other parts of Europe and in America.

Argillaceous Carbonate of Iron.

a. Clay Iron Stone, No. 453.

Haid. 2.408. Phil. 237. Leon. 235,6; 550,1.

The different clay iron stones appear to be carbonates of iron mixed with different proportions of silex, clay, and other foreign matters.

Carburet of Iron.

a. Graphite. *Black Lead. Plumbago*, No. 42.

Haüy, 4 85. Phil. 364. Haid. 2.191. Leon. 674.

Occurs in imbedded crystals of the form of regular hexagonal prisms, and massive. Primary form a Rhomboid. Cryst. fig. 106. P,P′ unknown. Cleavage parallel to the terminal planes of the prisms, very distinct, and the laminæ flexible. Fracture uneven. Hard. 1.0, 2.0. Sp.gr. 1.8, 2.1. Opaque. Lustre metallic. Colour iron or steel-grey, or blackish-grey. Streak black, shining.

Massive varieties, in irregular nodules and amorphous. Structure foliated, granular, compact.

Found in various parts of Europe and America, and appears to be intimately related to Anthracite.

The finest kind found in this Country occurs at Borradaile, in Cumberland.

The difference of composition between the foliated and granular varieties does not appear to have been ascertained.

b. Siderographite, No. 43.

Sill. 2.176. Leon. 716.

Resembles laminated plumbago. Sp.gr. 5.114. Magnetic. Consists of metallic iron and plumbago.

Found at Schooley's Mountain, New Jersey, North America.

Chromate of Iron.

a. Chromate of Iron, No. 420.

Haüy, 4.130. Phil. 210. Haid. 2.396. Leon. 557.

Occurs in imbedded octahedral crystals and grains, and massive. Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron. Fracture uneven. Hard. 5.5. Sp.gr. 4.0, 5.0. Opaque. Lustre imperfect metallic. Colour dark brown, black. Streak brown.

Massive varieties, amorphous. Structure granular, the grains sometimes separated by their partitions of talc coloured by chromic acid; compact.

Found in Scotland, in the Shetland Islands of Unst and Fetlar; in France, and other parts of Europe; in Siberia, and near Baltimore, at Hoboken, New Jersey, and some other places in North America.

Native Iron.

a. Meteoric?

Aerolite. *Meteorite*, No. 1.

Haüy, 3 531. Phil. 213. Haid. 2.442. Leon. 713.

Occurs disseminated in aerolites or meteoric stones, and in compact and vesicular masses, the cavities being sometimes filled with compact olivine. It is also said to have occurred crystallized in the form of the regular octahedron.

Primary form a Cube. Cryst. fig. 56. No apparent cleavage. Fracture hackly. Hard. 4.5. Sp.gr. 6.48, 7.768. Opaque. Lustre metallic. Colour pale steel-grey. Streak the same, shining.

Found in meteoric stones in various parts of the World. In compact and vesicular masses in Siberia, Peru, Mexico, North America, the Cape of Good Hope, and in several parts of Europe. Knives of meteoric iron were found in possession of some of the Esquimaux Tribes in North America.

b. Terrestrial Native Iron, No. 2.

Haüy, 3.531. Phil. 213. Haid. 2.442. Leon. 715.

Occurs massive in thin plates, ramose or cellular, sometimes covered by brown oxide of iron. Lustre metallic. Colour lighter than common iron.

Found near Grenoble in France, and at Steinbach, Eibestock, and Hamsdorf in Saxony.

S.J. 12.155. No. 3.

Occurs as a thin stratum, in a mass of mica slate, coated with crystalline graphite. Cleavage uncertain. Hardness the same as metallic iron. Sp.gr. 5.95, 6.72. Colour less silvery-white than meteoric iron. Malleable.

Found at Canaan, Connecticut, United States. Not alloyed with any other metal.

c. Terrestrial Native Iron containing Arsenic, No. 4.

S.J. 14.183. Leon. 663

Cleavage parallel to planes inclining to each other at about 120°. Fracture hackly. Hardness nearly that of ordinary steel. Sp.gr. 7.337. Lustre of

the cleavage planes highly metallic. Colour greyish, silver-white. Malleable.

Found in Bedford County, Pennsylvania, United States.

d. Volcanic Native Iron, No. 5.

Phil. 214.

Found in the Department of Puy de Dome in France, in a ravine formed by torrents across the lava and scoriæ of the mountain of Graveneire.

e. Terrestrial Native Steel? No. 6.

S.J. 12.155.

Found with the native iron at Canaan, Connecticut, in small angular fragments. Structure granular. Scratches glass. Colour silvery white. Brittle.

f. Volcanic Native Steel? No. 7.

Phil. 214.

Found near La Bouiche, in the Department of Allier, France, near a coal mine which appeared to have undergone spontaneous combustion.

Oxalate of Iron.

a. Humboldtine, No. 591.

Haüy, 4.139. Phil. 242. Haid. 3.110, Leon. 789.

Occurs crystalline and massive. Primary form not ascertained. Soft. Sp.gr. 1.3. Opaque. Dull. Colour brightish yellow.

Massive variety, small, flattish, reniform pieces. Structure fine earthy.

Found near Bilin in Bohemia.

Oxydulous Iron.

a. Magnetic Iron, No. 126.

Haüy, 3.560. Phil. 221. Haid. 2.399. Leon. 554.

Occurs in attached and imbedded crystals, arenaceous and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron, distinct, but in some varieties not obtainable. Fracture conchoidal, uneven. Hard. 5.5, 6.5. Sp.gr. 4.4, 5.1. Opaque. Lustre metallic, occasionally bright. Colour iron-black. Streak black.

Massive varieties, amorphous. Structure granular to compact.

Found in several parts of North and South America and Europe, and in the East Indies and China.

Titanium is frequently contained in magnetic iron, but the varieties containing it have not hitherto been well distinguished.

Oxide of Iron.

a. Crystallized and retaining the metallic lustre.

Oligiste Iron. *Specular Iron. Micaceous Iron*, No. 125.

Haüy, 4.5. Phil. 224. Haid. 2.404. Leon. 545.

Occurs in attached crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106. P,P′= 86° 10′. Cleavage parallel to the primary planes, and perpendicular to the axis. Fracture uneven, conchoidal. Hard. 5.5, 6.5. Sp.gr. 5.0, 5.251. Opaque. Lustre metallic. Colour deep steel-grey to iron-black, frequently with a brilliant iridescent tarnish on the surface. Streak red, and reddish-brown. Slightly magnetic.

Massive varieties, amorphous, structure foliated.

Found in the Isle of Elba, and in many other parts of Europe. It also occurs in the lava of Auvergne in France, and in that of Vesuvius.

b. Crystallized, but without metallic lustre, the crystals being very minute and thin, and frequently transparent

Goethite. *Pyrosiderite. Iron Froth.*

The first of these varieties occurs in very thin, transparent, crystalline plates, in the cavities of black Hematite. The iron froth consists of very thin, brownish-red, scaly particles, which are slightly coherent, with a greasy feel, and staining the fingers.

It is found plentifully in Devonshire and Lancashire, and generally accompanies other varieties of this species.

c. Fibrous, compact, and earthy masses.

Red Hematite.

Leon. 548.

1. Occurs in globular and botryoidal shapes. Structure fibrous, generally radiating. Sp.gr. 4.7, 5.0. Opaque. Sometimes with a metallic lustre externally; sometimes dull. Internally nearly dull. Colour externally bluish-grey, greyish-red, red; internally red. Streak red.

Found at Ulverstone in Lancashire, in considerable quantities, and in other parts of Great Britain and Europe.

2. Amorphous masses. Structure compact, and sometimes slaty. Sp gr. 3.5, 5.0. Fracture conchoidal. Lustre and colour nearly the same as the preceding variety.

3. Red ochre. Red clay-iron-stone, generally found in compact and earthy masses. The distinguishing character is the shining *red* stain they produce on the fingers.

Oxide of Iron, Zinc, and Manganese.

a. Franklinite, No. 127.

Phil. 226. Haid. 2.403. Leon. 551.

Occurs in attached crystals, granular and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron, very indistinct. Fracture conchoidal. Hard. 6.0, 6.5. Sp.gr. 4.87, 5.09. Opaque. Lustre metallic. Colour iron-black. Streak deep red-brown. Magnetic without polarity.

Massive varieties, amorphous. Structure granular, compact.

Found at Franklin, New Jersey, North America.

Oxide of Iron and Lead.

a. Beudantite, No. 136

An. N.S 11.195. Leon. 722.

Occurs in small aggregated crystals.

Primary form a Rhomboid, Cryst. fig. 106. P,P′= 92° 30′. Cleavage perpendicular to the axis. Hard. 4.0, 5.0. Nearly opaque. Lustre resinous. Colour black; in thin fragments deep brown. Powder greenish-grey.

Found at Horhausen on the Rhine.

Nepheline has also been named Beudantite.

Hydrate of Iron.

a. Hydrous Oxide of Iron. *Brown Iron-ore. Stilpnosiderite?* No. 143.

Haüy, 4.101. Phil. 226. 230. Haid. 2.411. Leon. 230.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71. M,M′ = 95° 14′. Levy. Cleavage parallel to the short diagonal. Fracture uncertain. Hard. 5.0, 5.5. Sp.gr. 3.93. Nearly opaque. Lustre adamantine. Colour brown, of various shades. Streak yellowish-brown.

Massive varieties. Brown hematite, globular, reniform, and some of the varieties of brown and yellow clay-iron-stone. Stalactitic, structure fibrous, or fibro-

laminar. Sometimes in pseudomorphous crystals.

Found in good crystals in Cornwall, and the other varieties in most parts of the World.

Oxide of Iron and Manganese?

a. UMBER, No. 128.

Phil. 232. Haid. 3.186.

Occurs massive, amorphous. Structure earthy. Fracture conchoidal. Soft. Sp gr. 2.2. Opaque. Dull. Colour yellowish and reddish-brown.

Found in the Isle of Cyprus.

Phosphate of Iron.

a. VIVIANITE, *Blue Iron*, No. 488.

Haüy, 4 126. Phil 238. Haid. 2.188. Leon. 137, 284.

Occurs in attached crystals, in imbedded crystalline aggregations, and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 105° 19′. M,M′ = 108°. Levy. Cleavage parallel to the oblique diagonal. Fracture indistinct. Hard. 1.5, 2.0. Sp.gr. 2.66, 2.70. Transparent, translucent. Lustre vitreous. Colour various shades of blue and green. Streak lighter colour.

Massive varieties, aggregations of crystalline particles, or globular and amorphous earthy masses.

Found crystallized in Cornwall, at Bodenmais in Bavaria, in Brazil, in New Jersey, North America, and in some other places.

The compact earthy varieties occur in several parts of Europe and America.

b. KARPHOSIDERITE? No. 489.

E J.S. 8.181.

Occurs in reniform masses. Structure granular, compact. Hard. 4 0, 4 5. Sp.gr. 2.5. Opaque. Lustre resinous. Colour pale and bright straw-yellow. Streak the same. Shining. Feels greasy. Much resembles iron sinter.

Found in Greenland.

Scheelate of Iron and Manganese.

a. WOLFRAM, No. 414.

Haüy, 4.366. Phil. 255. Haid. 2.387. Leon. 313.

Occurs in attached and imbedded crystals, massive, and pseudomorphous.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M′ = 110°. 50′. M,M′ = 101° 5′. Cleavage parallel to the terminal plane and to both its diagonals, that through the oblique diagonal very distinct. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 7.1, 7.3. Opaque. Lustre imperfect metallic. Colour dark brown, brownish-black. Streak dark brown.

Massive varieties, amorphous, structure crystalline, columnar. The pseudomorphous crystals are octahedrons resembling those of Scheelate of lime.

Found very generally in tin mines, and in other veins in primitive rocks.

Silicate of Iron.

a. CRONSTEDTITE, No. 281.

Phil. 227. Haid. 3.90. Leon. 211.

Occurs in small, thin, attached hexagonal prisms, sometimes in radiating groups, and massive. Primary form a Rhomboid. CRYST. fig. 106. Cleavage perpendicular to the axis, distinct. Hard. 2.0, 2.5. Sp.gr. 3.348. Opaque. Lustre vitreous. Colour black and brownish-black. Streak dull green.

Massive variety, reniform. Structure fibrous.

Found near Przibram in Bohemia, and in Cornwall.

b. SIDEROSCHISOLITE, No. 175.

E.J.S. 2.371. Leon. 778.

Occurs in small three-sided and six-sided pyramids attached by their apex. Cleavage parallel to the base of the pyramids. The face of cleavage smooth, the planes of the pyramids convex. Hard. 2.0, 3.0. Sp.gr. *probably* above 3.0.

Supposed to be a variety of Cronstedtite by Dr. Wernekingk, but the description is too imperfect for an exact comparison.

Found at Conhonas do Campo, Brazil.

c. THRAULITE, No. 176.

E J.S. N.S. 1.185.

Occurs in amorphous masses, accompanying iron pyrites, at Bodenmais, in Bavaria. Structure curved, foliated. Cross fracture uneven. Nearly opaque. Lustre vitreo-resinous. Colour brownish-black.

d. NONTRONITE, No. 177.

E.J.S. 10.150.

Occurs in small nodules imbedded in an ore of manganese. Fracture earthy. Opaque. Dull. Colour pale yellow, sometimes greenish. Streak shining. Unctuous to the touch and very tender.

Found near the village of St. Pardoux, Arrondissement of Nontron, Department of Dordogne, France.

e. CHLOROPAL, No. 174.

Phil. 378. Haid. 3.85. Leon. 179.

Occurs massive, amorphous. Structure compact, sometimes earthy. Fracture conchoidal, uneven. Hard. 3.0, 4.0. Sp.gr. 1.8, 2.0. Opaque. Lustre of the compact variety dull resinous. Colour green, sometimes reddish-brown.

Found near Unghwar, in Hungary.

f. GREEN IRON-EARTH? No. 357.

Haid. 3.106. Leon. 237.

Occurs reniform, botryoidal, globular, and amorphous. Surface smooth. Structure *thin fibrous*, curved lamellar, compact, sometimes pulverulent. Lustre resinous. Colour green, of several shades. Streak yellowish-grey.

Found at Schneeberg, in Saxony, and is a very imperfectly determined species.

The specimens which have appeared in this Country as green iron-earth are yellowish-green, with a fine granular fracture.

Silicate of Iron and Lime.

a. YENITE. *Ilvaite*, No. 280.

Haüy, 4.91. Phil. 24. Haid. 2.414. Leon. 528.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 61. M,M′ = 111° 30′. Cleavage parallel to the long diagonal of the prism. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 3.8, 4.0. Opaque. Lustre vitreous. Colour black, sometimes brownish or greenish. Streak the same.

Massive varieties, amorphous, structure columnar, compact.

Found principally at Rio la Marina, and Cape Calamita in the Isle of Elba, and in Silesia, Norway, Siberia, and North America.

Sulphate of Iron.

a. MELANTERITE. *Green vitriol*, No. 540.

Haüy, 4.140. Phil. 240. Haid. 2.41. Leon. 112.

Occurs in attached crystals, massive, fibrous, and earthy, resulting from the decomposition of other Minerals.

Primary form an Oblique rhombic prism, P,M = 99°

20′. M,M′ = 82° 20′. Cleavage parallel to all the primary planes. Fracture conchoidal. Hard. 2.0. Sp.gr. 1.832. Transparent, translucent. Lustre vitreous. Colour green, of several shades, yellow, and yellowish-brown. Streak white. Taste sweetish and astringent.

Massive varieties, amorphous, structure granular, botryoidal, reniform, stalactitic. Structure fibrous; in thin fibres, filling the fissures of decomposing shale.

Found in most mines in which sulphuret of iron occurs, and is frequently produced on the surface of cabinet specimens. It is also found in coal mines.

Red Sulphate of Iron?

a. BOTRYOGENE, No. 541.

E.J.S. 9.48.

Occurs in attached and aggregated crystals, the aggregations forming globular, botryoidal, and reniform shapes, with a crystalline surface.

Primary form an Oblique rhombic prism, P,M = 113° 37′. M,M′ = 119° 56′. Cleavage parallel to M,M′, distinct, and indistinct parallel to another prism of 81° 44′. Hard. 2.25, 2.5. Sp.gr. 2.039. Translucent. Lustre vitreous. Colour deep yellowish-red, yellow. Streak yellow. Less soluble than green sulphate.

Found in the great copper mine at Fahlun in Sweden.

Persulphate of Iron?

a. MISY, No. 543.

E.J.S. 9.51.

Occurs in the form of a yellow crystalline powder at Fahlun in Sweden, and at Goslar in the Hartz.

Cubic Sulphuret of Iron.

a. IRON PYRITES, No. 72.

Haüy, 4.38. Phil. 217. Haid. 2.457. Leon. 657.

Occurs in attached and imbedded crystals and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the primary planes, distinct, less so parallel to the planes of the regular octahedron. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 4.60, 5.03. Opaque. Lustre metallic. Colour brass-yellow. Streak brownish-black.

Massive varieties, amorphous; structure granular, compact. Globular, and stalactitic; the surface drusy; structure fibrous or columnar, radiating. Occasionally in separate fibres.

Found in most parts of the World, and in some mining districts in great abundance.

It sometimes contains gold; and in Sweden, Bohemia, and Anglesey in this Country a pale yellow variety occurs in granular masses, containing selenium.

Prismatic Sulphuret of Iron

a. WHITE IRON PYRITES, No. 73.

Haüy, 4.68. Phil. 220. Haid. 2.462. Leon. 660.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 106° 2′ Cleavage parallel to M and M′, distinct. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 4.678. Opaque. Lustre metallic. Colour pale whitish, greenish, or greyish-yellow. Streak greyish-black.

Massive varieties, botryoidal, reniform, stalactitic, and amorphous. Surface drusy. Structure diverging, fibrous, or columnar.

Found in most mining districts.

Magnetic Sulphuret of Iron.

a. MAGNETIC IRON PYRITES, No. 74.

Haüy, 4.64. Phil. 221. Haid. 2.465. Leon. 665.

Occurs in imbedded hexagonal crystals, and massive.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ not ascertained. Cleavage parallel to all the planes of a regular hexagonal prism. Fracture uneven. Hard. 3.5, 4.5. Sp.gr. 4.631. Opaque. Lustre metallic. Colour pale yellowish and brownish-red. Liable to tarnish. Streak greyish-black.

Massive varieties, amorphous. Structure foliated, granular, compact.

Found crystallized, accompanying native silver in Norway and the Hartz. Massive in Cornwall, Wales, North America, Bavaria, Saxony, and many other places.

Sulpho-arseniuret of Iron.

a. MISPICKEL. *Arsenical Iron*, No. 111.

Haüy, 4.28. Phil. 215. Haid. 2.448. Leon. 663.

Occurs in attached or imbedded crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 111° 12′. Cleavage parallel to the primary planes. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 6.127. Opaque. Lustre metallic. Colour tin-white, sometimes with a yellowish tarnish. Streak greyish-black.

Massive varieties, amorphous. Structure columnar, granular, compact.

Found in most metallic veins in the older rocks.

Sulphuret of Iron and Arsenic.

a. HÜTTENBERGITE. *Axotomous Arsenical Pyrites*, No. 112.

Haid. 2.448.

Occurs crystalline and massive.

Primary form a Right rhombic prism, CRYST. fig. 71. M,M′ = 122° 26′. Cleavage distinct, perpendicular to the axis of the prism. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 7.228. Opaque. Lustre metallic. Colour greyish-silver-white. Streak greyish-black.

Massive varieties, amorphous. Structure columnar, radiating, granular, fibrous? compact.

Found near Hüttenburg in Carinthia, at Reichenstein in Silesia, and at Schladming in Stiria.

Titaniate of Iron.

A very indiscriminate class of iron ores, some crystallizing in Cubes and others in Rhomboids, and requiring a careful revision.

The following descriptions have been given of some of the varieties.

a. IRON SAND, No. 389.

Haid. 2.402. Leon. 365. 554.

There are so many loose, granular, and sandy varieties of iron ore found in alluvial soil, that no general description can be given which will comprehend them all. They generally contain titanium, but occasionally consist of magnetic or oligistic iron only.

b. ISERINE. In larger grains, containing about 28 per cent. of oxide of Titanium.

c. MENACCANITE. Containing about 45 per cent.

d. NIGRINE, No. 390.

Phil. 258. Haid. 2.376. Leon. 362.

Haidinger describes this as Rutile; but specimens received in this Country as Nigrine, are altogether different, and resemble Menaccanite in lustre, colour, and appearance of the fractured surfaces.

This may, therefore, be regarded as an uncertain species.

e. AXOTOMOUS IRON, No. 391.

Haid. 2.397. Leon. 366.

Primary form a Rhomboid. CRYST. fig. 106. P,P' = 85° 40' nearly. Cleavage perpendicular to the axis, distinct. Fracture conchoidal. Hard. 5.0, 5.5. Sp.gr. 4.66. Opaque. Lustre imperfect, metallic. Colour black. Streak black.

Found at Gastein in Salzburg, in Sweden, and in Siberia.

f. CRICHTONITE, No. 392.

Haüy, 4.98. Phil. 261. Haid. 2.399. Leon. 367.

Occurs in attached crystals.

Primary form a Rhomboid. CRYST. fig. 106. P,P' = 61° 20', or 85° 40', nearly, according to the planes assumed to be the primary, there being no apparent cleavage planes parallel to either set. Cleavage perpendicular to the axis. Fracture conchoidal. Hard. 4.5. Sp.gr. 4.0. Opaque. Lustre imperfect metallic. Colour black. Streak black.

Found at Oisans in France.

The cleavage and other characters render it probable that this may not differ chemically from the axotomous iron of Mohs.

g. MOHSITE, No. 393.

P.M. and An. 1.221.

Occurs in attached macled crystals.

Primary form a Rhomboid. CRYST. fig. 106 P,P' = 73° 13'. No apparent cleavage. Fracture conchoidal. Hard. 5.5. Opaque. Lustre metallic. Colour black. Streak black. Not magnetic.

Found in Dauphiny, France.

ISOPYRE, No. 310.

P.M. and An. 3.70.

Occurs in amorphous masses in granite. Fracture conchoidal. Hard. 5.5, 6.0. Sp.gr. 2.912. Nearly opaque. Lustre vitreous. Colour black, or greyish-black, sometimes dotted with red. Streak greenish-grey. Slightly magnetic.

Found in the Western part of Cornwall, where it had been called black opal.

ITTNERITE, No. 211.

Leon. 749.

Occurs crystallized in Rhombic dodecahedrons and massive. Structure compact. Fracture uneven. Hard. 5.5. Sp.gr. 2.3. Lustre resinous to vitreous. Colour grey of different shades.

Found at Kaiserstuhl in Swabia.

KAKOXENE, No. 503.

E.J.S. 5.163. Leon. 749.

Occurs in thin fibrous radiating tufts or plates filling narrow fissures in a clayey-brown ironstone at Zbirow in Bohemia. Colour yellow of several shades and sometimes brownish-red.

KARPHOLITE, No. 312.

Phil. 22. Haid. 3.116. Leon. 209.

Occurs in slender crystals and silky fibres.

Primary form unknown. Sp.gr. 2.955. Lustre of the crystals vitreous, of the fibrous masses silky. Colour yellow, sometimes pale.

Found at Schlackenwalde in Bohemia.

KEFFEKILLITE, No. 358.

Leon. 181.

A Mineral from the Crimea, so named by Fisher of Moscow, not analyzed or described.

KILLINITE, No. 223.

Phil. 322. Haid. 3.117. Leon. 750.

Occurs in imbedded imperfect crystals and massive.

Cleavage parallel to the lateral planes and short diagonal of a rhombic prism of about 135°. Phil. Fracture uneven. Hard. 4.0. Sp.gr. 2.698. Translucent, opaque. Lustre dull vitreous. Colour brownish or yellowish-green, or greenish-grey. Streak yellowish-white.

Massive variety, amorphous, structure columnar, promiscuously arranged.

Found at Killiney near Dublin, Ireland.

KNEBELITE, No. 288.

Phil. 206. Haid. 3.118. Leon. 751.

Occurs massive, with a cellular and uneven surface. Fracture imperfectly conchoidal. Hard. Brittle. Difficultly frangible. Sp.gr. 3.714. Opaque. Lustre glistening. Colour grey, with spots of dirty white, brownish-red, brown, and green.

No locality given.

LABRADORITE. *Labrador Felspar. Felspath Opaline*, No. 234.

Haüy, 3.94. Phil. 115. Haid. 2.257. Leon. 430.

Occurs in rolled or imbedded crystalline masses. Cleavage parallel to all the planes of a Doubly oblique prism. CRYST. fig. 95. P,M = 93° 55'. P,T = 114° 26'. M,T = 120° 40' Fracture uneven. Hard. 5.5, 6.5. Sp.gr. 2.69, 2.76. Translucent. Lustre vitreous. Colour grey, white, with rich iridescent colours in particular directions.

Found principally in rolled masses on the coast of Labrador, and in Devonshire imbedded in a trap rock. The white variety, which may possibly be Cleavelandite, is from Greenland.

The above measurements, which were taken on distinct but not bright cleavage planes, approach so very nearly to those of Cleavelandite as to create a doubt whether they really differ.

LATROBITE. *Diploite. Amphodelite?* No. 316.

Phil. 380. Haid. 3.118. Leon. 465.

Occurs in attached and imbedded crystals and massive.

Primary form a Doubly oblique prism. CRYST. fig. 95. Measuring 91°, 93° 30', and 98° 30', nearly. Cleavage parallel to all the primary planes. Fracture uneven. Hard. 5.0, 6.0. Sp.gr. 2.72, 2.8. Translucent. Lustre vitreous. Colour pale red.

Found at Amitok Island, Labrador, and in Finland.

LAUMONITE, No. 217.

Haüy, 3.151. Phil. 45. Haid. 2.234. Leon. 200.

Occurs in attached and aggregated crystals and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 113° 30'. M,M' = 86° 15'. Cleavage parallel to M,M', distinct. Fracture uneven. Sp.gr. 2.2. Translucent, opaque. Lustre vitreous. Colour greyish, yellowish, reddish-white. Streak white.

Massive varieties, amorphous, structure granular.

By exposure to the air it loses its water of crystallization, and becomes friable.

Found at Huelguet in Brittany, in Hungary, Faroe, Iceland, Scotland, and Ireland.

LAVA, No. 250.

Leon. 181. 413.

Occurs as a volcanic product in more or less compact or vesicular masses. Fracture uneven. Hardness and Sp.gr. variable. Translucent, opaque. Lustre vitreous. Colour greyish and greenish-black, brown, red, grey.

Found at Vesuvius, Etna, and other volcanos.

LAZULITE. *Lapis Lazuli*, No. 564.

Haüy, 3.54. Phil. 44. Haid. 2.288. Leon. 136.460.

Occurs in imbedded dodecahedral crystals and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the rhombic dodecahedron, indistinct. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 2.76, 2.94. Translucent, opaque. Lustre vitreous. Colour blue of different shades. Streak paler blue.

Massive varieties. Amorphous, sometimes in small imbedded grains; structure fine granular, compact.

Brought from Persia and China, but neither its locality nor its geological relations are known.

Used in the manufacture of ultramarine, and in jewellery, as ornamental stones

LEAD.

Aluminate of Lead.

a. PLOMBGOMME, No. 151.

Haüy, 3.410. Phil. 338. Haid. 3.140. Leon. 229.

Occurs in small globular and reniform masses, composed of thin concentric layers. Structure of the layers indistinctly fibrous. Fracture uneven. Hard. 4.5, 5.0. Translucent. Colour yellow, sometimes brownish.

Found at Huelguet in Brittany.

Arseniate of Lead.

a. GORLANDITE. *Bleiniere* when in reniform masses, No. 475.

Haüy, 3.385. Phil. 345. Haid. 2.133. Leon. 272.

Occurs in attached crystals, in the form of regular hexagonal prisms, frequently with convex lateral planes, and massive.

Primary form a Rhomboid. CRYST. fig. 106 Cleavage parallel to the lateral planes of the hexagonal prism. Hard. 4.0, 5.0. Sp.gr. 5.0, 6.4. Transparent, translucent. Lustre resinous. Colour pale dull yellow, yellowish and reddish-brown.

Massive varieties, reniform, structure compact. Fracture conchoidal. Sp.gr. 3.9. Opaque. Lustre resinous. Colour brownish-red. From Nertschinsk in Siberia.

Found in Cornwall, at St. Prix in France, and in a few other places.

b. ARSENITE OF LEAD? No. 476.

Specimens of a pale yellow substance in fine fibres, soft, and easily reducible to an impalpable powder, have passed under this name, but we do not find any published account of it.

Carbonate of Lead.

a. CARBONATE OF LEAD, No. 458.

Haüy, 3.365. Phil. 338. Haid. 2.130. Leon. 290.

Occurs in attached crystals, in aggregations of columnar crystals, and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M' = 117° 14'. Cleavage parallel to all the primary planes. Fracture conchoidal. Hard. 3.0, 3.5. Sp.gr. 6.465. Transparent, translucent. Lustre adamantine on the cleavage planes, resinous on the fracture surfaces. Colour generally white, occasionally grey, yellow, green, black. Streak white.

Massive varieties, amorphous; structure columnar, granular, compact.

Found in most lead mines, and occasionally in those of other metals, in many parts of Europe, Asia, and America, and used as an ore of lead.

Chloride of Lead.

a. CHLORIDE OF LEAD, No. 63.

Occurs in small, thin, flat, white, opaque crystals, accompanying murio-carbonate of lead from Cornwall.

b. CHLORO-CARBONATE OF LEAD. *Murio-carbonate of Lead*, No. 65.

Haüy, 3.374. Phil. 343. Haid. 2.150. Leon. 294.

Occurs in attached crystals.

Primary form a Square prism. CRYST. fig. 65. Cleavage parallel to the primary planes, distinct. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 6.0. Transparent. Lustre adamantine. Colour white, pale grey, yellow, and green. Streak white.

Found at Matlock, Derbyshire, and in Cornwall.

c. BERZELITE. *Chloro-oxide of Lead*, No. 64.

Haid. 2.151. Leon. 416.

Occurs in crystalline amorphous masses. Cleavage parallel to the lateral planes, and short diagonal of a rhombic prism of 102° 30'. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 7.077. Translucent. Lustre adamantine. Colour yellowish-white, pale yellow, and red.

Found near Churchill, in the Mendip Hills, Somersetshire.

Chromate of Lead.

a. CHROMATE OF LEAD, No. 421.

Haüy, 3.357. Phil. 349. Haid. 2.137. Leon. 337.

Occurs in attached crystals and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 99° 10'. M,M' = 93° 30'. Cleavage parallel to the primary planes, indistinct. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 6.001. Transparent, translucent. Lustre adamantine. Colour red. Streak orange-yellow.

Massive varieties, amorphous; structure columnar, granular.

Found principally at Berezof in Siberia, and recently in Brazil.

Chromate of Lead and Copper

a. VAUQUELINITE, No. 422.

Phil. 350. Haid. 3.167. Leon. 339.

Occurs in minute attached crystals, and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. Fracture uneven. Hard. 2.5, 3.0. Sp gr. 5.5, 5 78. Nearly opaque. Lustre adamantine. Colour greenish-black, black. Streak greenish.

Massive varieties, botryoidal, reniform, amorphous; structure fine granular, compact.

Found at Berezof in Siberia, with chromate of lead.

Molybdate of Lead.

a. CARINTHITE, No. 417.

Haüy, 3.397. Phil. 348. Haid. 2.140. Leon. 340.

Occurs in attached crystals and massive.

Primary form a Square prism. CRYST. fig. 65. Cleavage parallel to the primary planes, and to those of *Mod. c.* CRYST. fig. 68. Fracture uneven. Hard. 3.0. Sp.gr. 6.760. Transparent, translucent. Lustre resinous. Colour yellow of different shades, greenish-red, and red.

Found chiefly in Carinthia, also in Austria, Hungary, and in North America. The red at Moldawa in the Bannat.

Oxide of Lead with Molyb. Carb. Mur. Phosp. and Chromic Acids.

a. PAMPLONITE, No. 418.

E.N.P.J. 12.142.

Occurs in small amorphous concretions in a decom-

posed syenite. Heavy. Sp.gr. 6.0. Colour greenish-yellow.

Found in the Paramo Rico, near Pamplona, South America.

Native Lead.

a. NATIVE LEAD, No. 10.

Phil. 332. Haid. 3.129. Leon. 695.

Occurs in small, amorphous, imbedded masses in lava or some other fused substances. Fracture hackly. Hard. 1.5. Sp.gr. 11.35. Opaque. Lustre metallic. Colour lead-grey. Streak shining.

Found in Madeira and some other places, and at Alston in Cumberland.

Red Oxide of Lead.

a. NATIVE MINIUM, No. 135.

Haüy, 3.352. Phil. 337. Leon. 559.

Occurs in compact and pulverulent amorphous masses, supposed to arise from the decomposition of galena. Hard. 2.0, 2.5. Sp.gr. 4.6. Dull. Colour bright red.

Found in Yorkshire, in Swabia, Siberia, and some other places.

Yellow Oxide of Lead.

a. NATIVE MASSICOT, No. 134.

An. 5.47. Leon.

Occurs in amorphous masses. Fracture earthy. Brittle. Sp.gr. 8.0. Opaque. Dull externally, internally semi-metallic. Colour yellow.

Found at Eschweiler.

Phosphate of Lead.

a. PYROMORPHITE, No. 493.

Haüy, 3.385. Phil. 344. Haid. 2.133. Leon. 272.

Occurs in attached crystals, generally in the form of regular hexagonal prisms, frequently with the lateral planes convex, sometimes slender and fasciculated; and massive.

Primary form a Rhomboid. CRYST. fig. 106. Cleavage parallel to all the planes of the prism, and to the truncation of its terminal edges. Fracture uneven. Sp.gr. 7.098. Transparent, translucent. Lustre resinous. Colour grey, green, brown.

Massive varieties, globular, reniform, botryoidal; structure fibrous. Amorphous structure fibrous, granular, compact.

Found in most lead mines.

b. PHOSPHATO-ARSENIATE OF LEAD, No. 494.

Haüy, 3.385. Phil. 345. Haid. 2.133. Leon. 272.

Occurs in attached and aggregated crystals similar in form and most other characters to phosphate. Colour various shades of yellow.

Scheelate of Lead.

a. SCHEELATE OF LEAD, No. 415.

Phil. 350. Haid. 3.165. Leon. 345.

Occurs in attached and aggregated crystals.

Primary form a Square prism, (CRYST. fig. 65,) of the same dimensions as that of Molybdate of lead. Cleavage perpendicular to the axis of the prism, and parallel to planes of *Mod. c*, CRYST. fig. 68. Fracture conchoidal. Hard. 3.0. Sp.gr. 8.0. Translucent. Lustre resinous. Colour yellowish and brownish-grey.

Found at Zinnewald in Bohemia, and Bleiberg in Carinthia.

Seleniuret of Lead.

a. SELENIURET OF LEAD, No. 47.

An. N.S. 10.233. 284. Leon. 590.

Occurs in amorphous masses; structure granular, and nearly resembling fine-grained galena. Softer than galena. Sp.gr. 7.697. Opaque. Lustre metallic, rather dull. Colour more blue than galena.

Found at Clausthal and Tilkerode in the Hartz, accompanied by some of the following varieties·

b. Seleniuret of lead and cobalt, No. 48.

c. ... ... *copper*, No. 49.

d. Cupriferous seleniuret of lead, No. 50.

e. Seleniuret of lead and mercury, No. 51.

f. ... ... *copper and silver*, No. 52.

These are said to resemble seleniuret of lead so nearly as to be scarcely distinguishable from it.

Sulphate of Lead.

a. ANGLESITE, No. 548.

Haüy, 3.402. Phil. 346. Haid. 2.142. Leon. 249.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. $M,M' = 103° 42'$. Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 2.5, 3.0. Sp.gr. 6.298. Transparent, translucent. Lustre approaching to adamantine. Colour white, sometimes greyish, yellowish, greenish, grey, and brown of several shades, black. Streak white.

Massive varieties, amorphous, structure laminar, granular, compact.

Found in lead and copper mines at Lead hills, Scotland, in Anglesey, in Cornwall, the Hartz, and other places in Europe, and in North America.

Cupreous Sulphate of Lead.

a. LINARITE, No. 549.

Phil. 347. Haid. 2.143. Leon. 251. P.M. and An. 10.267.

Occurs in attached crystals.

Primary form an Oblique rhombic prism. CRYST. fig. 83. $P,M = 96° 25'$. $M,M' = 61°$. Cleavage parallel to P, and to the horizontal diagonals of the terminal planes. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 5.3, 5.43. Transparent, translucent. Lustre adamantine. Colour deep blue. Streak pale blue.

Found at Linares in Spain, and at Lead hills, Scotland.

Sulphate and Carbonate of Lead.

a. LANARKITE. *Sulphato carbonate of Lead*, No. 550.

Phil. 341. Haid. 2.148. Leon. 253.

Occurs in long, slender crystals, single or aggregated into fibrous masses.

Primary form an Oblique rhombic prism, the angles of which have not been ascertained. The crystals are lengthened in the direction of the horizontal diagonals of the terminal planes. Hard. 2.0, 2.5. Sp.gr. 6.8, 7.0. Transparent, translucent. Lustre nearly resinous, but pearly on the cleavage planes. Colour greenish, yellowish, or greyish. Streak white.

Found at Lead hills in Scotland.

b. CALEDONITE. *Cupreous-sulphato-carbonate of Lead*, No. 551.

Phil. 342. Haid. 2.149. Leon. 254.

Occurs in attached crystals.

Primary form a Right rhombic prism. CRYST. fig. 71. $M,M' = 95°$. Cleavage parallel to the primary planes, and to the short diagonal of the prism. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 6.4. Transparent, translucent. Lustre resinous. Colour blue and greenish-blue. Streak bluish or greenish-white.

Found at Lead hills in Scotland.

c. SUZANNITE. *Sulphato-tri-carbonate of Lead*, No. 552.
Phil. 341. Haid. 2.144. Leon. 252.
This Mineral occurs, as carbonate of lime does, under two forms. One an Acute rhomboid, CRYST. fig. 106, P,P′ = 72° 30′; and the other a Right rhombic prism, CRYST. fig. 71, M,M′ = 120°.
Mr. Haidinger has regarded this last as an *Oblique* rhombic prism, a difference of opinion which may perhaps be explained by his own observations on Mr. Levy's *Humboldtite*; the compound figures given by him in *Edinb. Phil. Trans.* 10.217. being purely imaginary.
The cleavage of both forms is perpendicular to the axis, and very distinct. Hard. 2.5. Sp.gr. 6.3. Transparent, translucent. Colour grey-brown, yellow, green of various shades. Streak white.
Found at Lead hills in Scotland.

Sulphuret of Lead.

a. GALENA, No. 83.
Haüy, 3.341. Phil. 332. Haid. 3.13. Leon. 625.
Occurs in attached crystals, and massive.
Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 2.5. Sp.gr. 7.568. Opaque. Lustre metallic. Colour lead-grey. Streak the same.
Massive varieties, amorphous, structure granular, compact.
Found abundantly in many places in Europe, Asia, and America.
Sulphuret of lead is occasionally found to contain antimony, arsenic, silver, bismuth, and copper.

Sulphuret of Lead, Antimony, and Copper.

a. BOURNONITE. *Endellione. Triple Sulphuret*, No. 97.
Phil. 336. Haid. 3.5. Leon. 613.
Occurs in attached crystals and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 93° 30′ nearly. Cleavage parallel to the primary planes, and to both the diagonals of the prism. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 5.763. Opaque. Lustre metallic. Colour approaching to steel-grey, sometimes blackish-grey. Streak the same.
Massive varieties, amorphous, structure granular, compact.
Found in Cornwall, and in several parts of Europe, and in Peru.

Vanadiate of Lead.

a. JOHNSTONITE, No. 484.
E.J.S. N.S. 5.166.
Occurs in attached hexagonal crystals, and small globular concretions, frequently sprinkled over a surface of Calamine.
Primary form a Rhomboid. CRYST. fig. 106. Fracture conchoidal. Sp.gr. 6.99, 7.23. Translucent. Opaque. Lustre of the fractured surface resinous. Colour yellow and reddish-brown. Streak white.
Found at Wanlockhead in Scotland.

LEELITE, No. 317.
Phil. 21. Haid. 3.119. Leon. 757.
Occurs in amorphous masses.
Structure compact. Fracture conchoidal. Sp.gr. 2.7. Slightly translucent. Lustre waxy. Colour flesh-red.
Found at Gryphytta in Sweden, and, when first discovered, passed under the name of red hornstone.

LEUCITE. *Amphigene*, No. 233.
Haüy, 3.61. Phil. 107 Haid. 2.220. Leon. 435.
Occurs in imbedded trapezohedral crystals, and massive.
Primary form a Cube. Cleavage parallel to the planes of the cube and rhombic dodecahedron. Fracture conchoidal. Hard. 5.5, 6.0. Sp.gr. 2.483. Transparent to opaque. Lustre vitreous. Colour greyish, yellowish, or reddish-white, and different shades of grey. Streak white.
Massive variety, amorphous, structure granular.
Found in the lavas of Vesuvius, and the basalts of Italy and Bohemia.

LEVYNE, No. 206.
Haid. 3.120. Leon. 758.
Occurs in attached crystals, lining cavities in trap rocks.
Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 79° 29′. Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 4.0. Sp.gr. 2.15. Translucent. Lustre vitreous. Colour white. Streak white.
Found at Dalsnypen in Faroe, in Ireland, and in a few other places.
It is said by Berzelius to be a variety of *Chabasie*.

LHERZOLITE, No. 359.
Gal. 168. Leon. 505.
Occurs in imperfectly formed crystalline grains, imbedded in greenish-yellow steatite. Sp.gr. 3.54. Transparent. Colour emerald-green.
Found on the banks of Lake Lherz, in the mountains Du Couserans, Pyrenees.

LIGURITE, No. 318.
Phil. 207. Haid. 3.121. Leon. 758.
Occurs in imbedded crystals in a talcose rock.
Primary form an Oblique rhombic prism. CRYST. fig. 63. M,M′ = 140°. Fracture uneven. Hard. 5.0, 6.0. Sp.gr. 3.49. Transparent, translucent. Lustre vitreo-resinous. Colour yellowish-green. Streak greyish-white.
Found on the banks of the Stura in the Apennines.
Specimens of yellowish-green Sphene have been brought to this Country as Ligurite. This, however, cannot be the Mineral examined by Viviani, if his analysis be correct; for his Mineral does not contain a particle of titanic acid, of which Sphene contains from 33 to 40 per cent.

LIMBILITE, No. 360.
Phil. 208. Leon. 533.
Occurs in irregular grains in the volcanic hill of Limbourg. Structure compact. Hard. 6.0, 7.0. Colour honey-yellow.

LIME.

Arseniate of Lime.

a. PHARMACOLITE, No. 466.
Haüy, 1.587. Phil. 178. Haid. 3.135. Leon. 160. E.J.S. 3.302, 6.317.
Occurs generally in small, silky tufts, or minute globular and botryoidal fibrous masses, coating other substances, and very rarely in attached crystals.
Crystallized.
Primary form an Oblique rhombic prism. CRYST. fig. 83. M,M′ = 117° 24′. Cleavage parallel to the oblique diagonals of the terminal planes. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 2.730.

Mineralogy

Transparent, translucent. Lustre vitreous. Colour yellowish-white. Streak white. Thin laminæ are flexible.

Locality unknown.

Fibrous.

Very soft. Sp.gr. 2.64. Translucent, opaque. Lustre vitreous, pearly, dull. Colour white, greyish and reddish-white.

Found at Andreasberg, Hartz, in Thuringia, and some few other places.

b. HAIDINGERITE, No. 467.

E.J.S. 3.303, 6.317. Leon. 160.

Occurs in attached crystals, and in pearly, botryoidal, crystalline coats.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 100°. Cleavage parallel to the short diagonal of the terminal planes, very distinct. Hard. 2.0, 2.5. Sp.gr. 2.848. Transparent, translucent. Lustre vitreous. Colour white. Streak white. Thin laminæ slightly flexible.

Locality unknown.

Boro-silicate of Lime.

a. DATHOLITE, No. 126.

Haüy, 1.590. Phil. 177. Haid. 2.222. Leon. 285.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. CRYST. fig 73. M,M′ = 103° 40′: Phil. Cleavage parallel to the lateral planes, very indistinct. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.989. Translucent, opaque. Lustre vitreous, that of the fracture surfaces slightly resinous. Colour greyish, yellowish, greenish-white. Streak white.

Massive variety, amorphous, structure granular.

Found at Arendal in Norway.

b. HUMBOLDTITE, No. 427.

Phil. 380. Haid. 2.222. Leon. 286. 789.

Occurs in attached crystals.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,*h*, fig. 91 = 91° 41′. M,M′ = 115° 45′. Levy. Cleavage parallel to the oblique diagonal of the prism. Fracture conchoidal. Hard. 4.5, 5.0. Sp.gr. 2.99. Transparent, translucent, opaque. Lustre vitreous. Colour white, sometimes yellowish. Streak white.

Found in the Tyrol, in the Hartz, in North America, and in the neighbourhood of Edinburgh.

It is probable that this will be found to correspond with *Datholite* in form and measurement, as it does in chemical composition; and that Mr. Levy has been deceived by the imperfection of the crystals he examined.

c. BOTRYOLITE, No. 428.

Hauy, 1.591. Phil. 177. Haid. 2.222. Leon. 287.

Occurs in reniform, globular, and botryoidal masses. Structure fibrous, in concentric coats. Sp.gr. 2.8. Translucent on the edges, sometimes opaque and earthy. Colour pale yellowish and reddish-grey, occasionally black on the surface. Streak white.

Found at Arendal in Norway.

Rhomboidal Carbonate of Lime, **No. 441.**

1. *Crystallized.*

a. CALCITE. *Calcareous Spar. Iceland Crystal.*

Haüy, 1.298. Phil. 147. Haid. 2.83. Leon. 309.

Occurs in attached and imbedded crystals and crystalline masses, and occasionally stalactitic.

Primary form a Rhomboid. CRYST. fig. 106. P, P′ = 105° 5′. Cleavage parallel to the primary planes, very distinct. Fracture conchoidal, seldom observable. Hard. 3.0. Sp.gr. 2.721. Transparent, translucent. Lustre vitreous. Colour generally white, occasionally grey, blue, green, yellow, red, brown, black. Streak white, or slightly coloured.

Found in veins and in rocks of every formation in all parts of the World.

2. *Foliated.*

a. SCHIEFERSPAR. *Slate Spar.*

Haüy, 1.430. Phil. 149. Haid. 2.83. Leon. 316.

Occurs massive. Structure laminar, the laminæ being thin and generally curved or wavy. Sp.gr. about 2.5. Translucent. Lustre vitreous on the edges, pearly on the surface of the laminæ. Colour white, sometimes reddish, yellowish, greenish. Streak white.

Found in England, Scotland, Ireland, and in other parts of the World.

3. *Pearly.*

a. APHRITE. *Ecume de Terre. Schaumerde.*

Phil. 150. Haid. 3.72. Leon. 776.

Occurs in thin, white, pearly scales or plates. Hard. 0.5, 1.0. Sp.gr. 2.5. Opaque. Lustre pearly in a high degree. Colour white. Streak white.

Found in Saxony, Hessia, and some other places.

4. *Columnar.*

a. ANTHRACONITE. *Madreporite.*

Hany, 1.358. Phil. 160. Haid. 2.83. Leon. 317.

Occurs in roundish masses. Structure columnar, diverging. Hard. 3.0. Sp.gr. 2.7. Opaque. Lustre vitreous. Colour greyish-black.

Found in Norway, Sweden, Greenland, and one or two other places.

5. *Fibrous.*

a. STALACTITE.

Haüy, 1.364. Phil. 151. Haid. 2.83. Leon. 319.

Occurs reniform, stalactitic, tubular, and in other imitative shapes. Structure fibrous. Translucent, opaque. Lustre resinous, waxy, sometimes silky. Colour white with shades of grey, brown, red, yellow, and other colours. Streak whitish.

Found in fissures and caverns, in calcareous rocks, and occasionally in metallic veins.

6. *Granular and compact.*

a. MARBLE. *b.* LIMESTONE.

Haüy, 1.359. Phil. 152. Haid. 2.83. Leon. 316.

Occurs massive, the masses sometimes forming considerable mountains.

Those varieties which are capable of receiving a fine polish are commonly termed *Marble,* the purest and most crystalline of which are employed in statuary. The Pentelic, found near Athens, and the Carrara from the Gulf of Genoa, are the most esteemed.

The less pure varieties, which are generally less crystalline in their appearance, and more compact in their structure, although they differ much from each other in colour and composition, pass under the common name of *Limestone,* and are applied to many well-known economical purposes. Some of the common limestones contain a considerable proportion of silex, alumina, and other earths. The *Calp* in Ireland, the *Aberthaw* and the *Lias* in this Country, and the *Septaria,* or Nodules, as they are termed, found in the London clay, and of which the Roman cement is made, are impure

limestones. The impurity, however, rendering them more valuable as cements.

The fracture of the granular varieties is uneven and splintery, that of the more compact is even and flat conchoidal. Hardness and Sp.gr. rather below that of calcareous spar. Translucent to opaque. Lustre variable. Of almost all colours. Streak white or slightly coloured

Found abundantly in every part of the World.

7. *Earthy.*

a. CHALK. *Agaric Mineral. Rock Milk.*

Haüy, 1.362. Phil. 158. 150. Haid. 2.83. Leon. 321.

Chalk occurs in beds of very considerable extent. Fracture earthy. Soft. Sp.gr. about 2.3. Opaque. Dull. Colour white, sometimes yellowish or greyish. Is meagre to the touch.

Agaric Mineral is a spongy carbonate of lime, the particles of which are less coherent than those of chalk, with which it agrees in colour and most of its other characters.

Rock Milk is an absurd name for a variety of carbonate of lime, which occurs in the form of a fine white powder in the crevices of calcareous rocks.

Found in several parts of England, and in other Countries.

8. *Globular Concretions*

a. PISOLITE. *Peastone.*

Haüy, 1.369. Phil. 158. Haid. 2.83. Leon. 319.

Occurs massive, consisting of globules from one-eighth to half an inch in diameter, imbedded in a calcareous cement. Opaque. Colour brownish, reddish, yellowish-white. Streak white.

Found at Carlsbad, and a few other places

b. OOLITE. *Roestone.*

Haüy, 1.360. Phil. 157. Haid. 2.83. Leon. 318.

Occurs massive, in beds of considerable extent, formed of small globules of different sizes, seldom as large as one-eighth of an inch in diameter, cemented together by calcareous matter. Opaque. Dull. Colour greyish, brownish, yellowish white. Streak white.

The Bath stone affords a good example of this substance

9. *Incrusting. Sedimentary.*

a TUFA. *Travertino.*

Haüy, 1.370. Phil. 160. Haid. 2.63. Leon. 320.

The most impure and irregular of all the varieties of carbonate of lime, varying considerably in the cohesion of its particles, from a nearly pulverulent state (some Tufas) to that of a compact building stone. (Travertino.) It is a concrete production of many springs and streams in this and other Countries, and may be observed in abundance at Matlock in Derbyshire, near Cambridge, near Ventnor in the Isle of Wight, and in some other places.

It is found incrusting grass and moss at the edges of the water, and stems, leaves, and other substances immersed in it. Small baskets and birds' nests coated with this deposit, are sold as objects of curiosity.

Prismatic Carbonate of Lime, No. 442.

a. ARRAGONITE. The coralloidal variety, *Flos-ferri.*

Hauy, 1.432. Phil. 161. Haid. 2.79. Leon. 324.

Occurs in attached and imbedded, simple and compound crystals, frequently acicular, and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 116° 10′. Cleavage parallel to the lateral planes. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 2.9. Transparent, translucent. Lustre vitreous. Colour white, grey, reddish-brown. Streak greyish-white.

Massive varieties. Globular, reniform, coralloidal, and amorphous. Structure fibrous, either parallel or diverging, and sometimes, although rarely, compact.

Found in several places in England, Scotland, and Ireland, and in many other Countries. The best crystals occur at Arragon, in Spain, whence the name, at Leogang in Salzburg, and near Bilin in Bohemia. And very perfect masses of the branched variety (flos-ferri) at Dufton, and in the Quantock hills in Somersetshire.

b. SATIN SPAR?

Phil. 150. Haid. 2.83. Leon. 315.

Occurs in tabular masses of one or two inches thick, in veins in slaty clay or shale. Structure fibrous, the fibres parallel, generally waved, and always transverse to the direction of the vein. Harder than calcareous spar. Sp.gr. 2.7. Translucent. Lustre silky. Colour white, sometimes yellowish or greyish.

Found at Alston Moor in England, in Scotland, and in North America.

Carbonate of Magnesia and Lime.

1. *Crystallized.*

a. *The surfaces flat, or nearly so.*

BITTERSPAR. *Miemite. Tharandite*, No. 447.

Haüy, 1.427. Phil. 162. Haid. 2.91. Leon. 305.

Occurs in attached and imbedded crystals, and amorphous masses.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 106° 15′. Cleavage parallel to the primary planes, distinct. Fracture conchoidal. Hard. 3.5, 4.0. Sp.gr. 2.884. Transparent, translucent. Lustre vitreous, occasionally pearly. Colour white, grey, black, brown, yellow, green, of different shades. Streak greyish-white.

Found in the Tyrol in talc, in Piedmont, at Miemo in Tuscany, and in some other places. But there are few localities in which good crystals are produced.

b. *The planes curved.*

PEARLSPAR. *Brown Spar* (in part.)

Haüy, 1.421. Phil. 165. Haid. 2.94. Leon. 305.

Occurs in attached and generally aggregated crystals with curved surfaces.

Primary form a Rhomboid. CRYST. fig. 106. Probably of the same angles as bitterspar, but from the curvature of the planes they cannot be measured. Translucent. Lustre pearly. Colour white, sometimes greyish, brownish, or yellowish.

Found in many parts of Europe and America.

2. *Granular.*

a. DOLOMITE. *Magnesian Limestone. Conite.*

Leon. 305.

Occurs in mountain masses. Structure sometimes slaty. Fracture irregular. Softer than common limestone. Translucent, opaque. Colour white, sometimes greyish or yellowish.

The Apennines are partly composed of *Dolomite*, and the *magnesian limestone* is found in an extensive bed lying between Nottingham and Sunderland. It also occurs in other parts of the World. Some of the varieties are flexible when split or cut into

thin slabs. *Conite* is found only in Iceland. Is described as having a fracture imperfectly conchoidal, and is said to scratch glass, whence it is probable that it does not belong to this species. Sp.gr. 3.0. Opaque. Dull. Colour flesh-red.

3. *Compact.*

a. GURHOFIAN.

Phil. 106. Haid. 2.94. Leon. 308.

Occurs massive. Amorphous. Structure compact. Fracture flat conchoidal. Opaque. Dull. Colour white, sometimes yellowish. Streak white.

Found near Gurhoff, in Lower Austria.

Carbonate of Magnesia, Lime and Iron, No. 449.

P.M. and An. 2.231.

a. Occurs crystallized in rhomboids. Sp.gr. 2.927. Colour yellowish white.

Found at Tenzen in the Grisons.

E.J.S. 2.179.

b. Occurs in crystalline masses, cleavable into rhomboidal laminæ. Sp gr. 2.64. Opaque. Colour brown.

Found at Montiers in Savoy.

c. Crystalline masses. Sp.gr. 2.9. Colour violet-blue.

Found at Notre-Dame-du-Pré in Savoy, and is supposed to contain free oxide of iron.

No angles given of either of these varieties, the chemical elements of which differ in their proportions.

Carbonate of Lime and Iron.

a. ANKERITE. *Rohwand. Wandstein* of Stiria. No. 444.

Haid. 2.100. Leon. 308.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 106° 12′. Cleavage parallel to the primary planes. Fracture uneven. Lustre vitreous, inclining to pearly. Hard. 3.5, 4.0. Sp.gr. 3.080. Translucent. Colour white, with tints of grey, brown, red, yellow. Streak white.

Found in Salzburg resting on beds of mica slate, and all along the chain of the Alps, resting on carbonate of iron.

The planes are generally curved, and the measured angle is probably not correct.

b. MESITINE SPAR? No. 448.

E.J.S. 8.181.

Analysis not given, but supposed to contain lime, magnesia, oxides of iron and manganese. Primary form a Rhomboid. CRYST. fig. 107. P,P′ = 107° 14′: *Breit.* Cleavage parallel to the primary planes. Hard. 3.0. Sp.gr. 3.34. 3.37. Transparent, translucent. Lustre vitreous. Colour dark greyish and yellowish-white. Streak white.

Found in small crystals in quartz at Traversella in Piedmont.

Carbonate of Lime and Lead.

a. PLUMBOCALCITE, No. 445.

E.J.S. N.S. 6 79.

Occurs in attached crystals and crystalline masses.

Primary form a Rhomboid. CRYST. fig. 106. P,P′= 105° 5′. Cleavage parallel to the primary planes, distinct. Hard. under 3.0. Sp.gr. 2.824. Transparent, translucent. Lustre vitreous, sometimes pearly. Colour white. Streak white.

Found at Wanlockhead, Lanarkshire, Scotland, among the rubbish of some old workings.

Fluate of Lime.

a. FLUOR. *Fluor Spar*, No. 506.

Haüy, 1.505. Phil. 168. Haid. 2.69. Leon. 576.

Occurs in attached and imbedded crystals and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the regular octahedron, distinct, but seldom with perfect surfaces. Fracture conchoidal. Hard. 4.0. Sp.gr. 3.14. Transparent, translucent. Lustre vitreous. Colour white, grey, black, brown, red, yellow, green, blue, purple. Streak white or slightly coloured

Massive varieties, nodular: amorphous. Structure of the nodular variety large fibrous, or columnar, the fibres divergent. Structure of the amorphous, crystalline, granular, earthy, compact, and occasionally straight or curved laminar.

Crystallized Fluor is found abundantly in England, and in some other parts of Europe. In America it occurs less frequently. The nodular variety is found only in Derbyshire; the granular and earthy in England, Norway, and some parts of Germany; and the compact in Cornwall, the Hartz, and a few other places.

b. FLUO-ARSENIATE OF LIME, No. 507.

An. 6.151.

Occurs as a yellowish crust or coating on quartz or felspar, accompanying the oxide of tin, at Finbo, near Fahlun, in Sweden.

Native Lime.

a. NATIVE LIME, No. 117.

Br.M. pl. No. 1.

Occurs amorphous. Structure earthy. Easily rubbed to a powder. Opaque. Dull. Colour white.

Found near Bath.

Nitrate of Lime.

a. NITRATE OF LIME, No. 519.

Phil. 177. Leon. 248.

Occurs in fibrous efflorescences, or as a fine powder, on the surface of old walls, caverns, and some calcareous rocks. The fibres are often aggregated into silky-looking tufts. Very deliquescent. Taste bitter.

Phosphate of Lime.

a. APATITE. *Asparagus Stone. Moroxite. Phosphorite. Terre de Marmarosch*, No. 485.

Haüy, 1.487. Phil. 167. Haid. 2.73. Leon. 282.

Occurs in attached and imbedded crystals and crystalline masses, massive and earthy.

Primary form a Rhomboid. P,P′ = 88° 41′: Haid. Cleavage parallel to the planes of a regular hexagonal prism. Fracture conchoidal. Hard. 5.0. Sp.gr. 3.18, 3.22. Transparent, translucent. Lustre vitreous, sometimes inclining to resinous. Colour white, grey, brown, reddish, yellow, green, blue, violet. Streak white.

Found in Cumberland, Cornwall, in Saxony, Bohemia, and many other parts of Europe and America.

Massive varieties, globular; nodular; reniform; amorphous. Structure fibrous, granular, compact.

Found at Schlackenwald in Bohemia, and in Estremadura in Spain.

Earthy variety, greyish or greenish-white.

Found near Marmarosch in Hungary.

Scheelate of Lime.

a. TUNGSTEN. *Tungstate of Lime*, No. 413.

Haüy, 4.372. Phil. 256. Haid. 2.113. Leon. 346.

Occurs in attached and imbedded crystals and massive.

Primary form a Square prism. CRYST. fig. 61. Cleavage parallel to *Mod. a* and *c*, fig. 62 and 64. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 5.5,

6.076. Translucent. Lustre vitreous. Colour white, sometimes greyish and yellowish, and greyish and reddish-brown. Streak white.

Found in Cornwall and Cumberland in England, in Bohemia, Sweden, and other places in Europe, and in America.

Silicate of Lime.

a. WOLLASTONITE. *Tabular Spar*, No. 161.

Haüy, 2.438. Phil. 23. Haid. 2.286. Leon. 524. P.M. and An. 10.190.

Occurs in attached and imbedded crystals, and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M=104° 48′. M,M′ = 95° 38′. Cleavage parallel to the terminal plane and horizontal diagonal. Fracture uneven. Hard. 4.0, 5.0. Sp.gr. 2.8, 2.86. Transparent, translucent. Lustre vitreous, in some varieties pearly on the cleavage surfaces. Colour white, sometimes greyish, brownish, reddish, yellowish, greenish. Streak white.

Massive varieties, amorphous, composed of small columnar crystals lying in all directions, or fibrous, the fibres parallel or divergent.

Found in very perfect crystals at Vesuvius. Its other localities are Capo di Bove near Rome, the Bannat, Lake George in North America, and a few other places.

b. OKENITE, No. 162.

E J.S. N.S. 3.27.

Occurs in fibrous masses, having a radiated structure. Hard. 4.0, 5.0. Sp.gr. 2.28. Colour white.

Found in amygdaloid, at Disco Island, Greenland.

Sulphate of Lime, No. 532.

a. Crystallized.

SELENITE. *Gypsum.*

b. Massive.

ALABASTER. *Gypsum.*

Haüy, 1.527. Phil. 174. Haid. 2.57. Leon. 122.

Occurs in attached and imbedded crystals, and massive.

Primary form an Oblique rhombic prism. P,M = 111° 34′; M,M′ = 138° 38′; Levy. Cleavage parallel to the oblique diagonals, very distinct, and parallel to the primary planes, indistinct. Fracture indistinct. Hard. 1.5, 2.0. Sp.gr. 2.310, 2.5. Transparent, translucent. Lustre vitreous, on cleavage planes pearly. Colour white, occasionally grey, reddish, yellow, blue. Streak white.

Massive varieties, globular and nodular, structure granular. Amorphous, structure granular, earthy, compact, fibrous, scaly, the scales slightly coherent.

Found in very many parts of Europe and America, and probably in other parts of the World. It is abundant in imbedded crystals at Shotover in Oxfordshire, and has occurred in very perfect crystals at Bex in Swisserland.

When calcined and reduced to powder, it is Plaster of Paris. It enters into the composition of some kinds of porcelain and glass. Is employed in agriculture as a manure, and forms the paste of crayons for drawing. The compact varieties are employed in sculpture.

Anhydrous Sulphate of Lime.

a. ANHYDRITE. *Muriacite. Pierre de Trippes. Vulpinite*, No. 533.

Haüy, 1.562. Phil. 172. Haid. 2.62. Leon. 267.

Occurs in attached crystals, rarely well formed, and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 100° 8′. Cleavage parallel to the lateral planes, indistinct; to the terminal planes and their two diagonals very distinct. Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 2.5, 3.0. Transparent, translucent. Lustre vitreous, pearly on the cleavage surfaces. Colour white, grey, pale red, blue, violet. Streak greyish-white.

Massive varieties, nodular, contorted, amorphous. Structure granular, compact, fibrous.

Found at Halle in the Tyrol, at Bex in Swisserland, and in several other parts of Europe.

Titaniate of Lime, &c.

a. PYROCHLORE, No. 395.

E.J.S. 6.358.

Occurs in imbedded octahedral crystals.

Primary form a Cube. CRYST. fig. 56. Fracture uneven. Hard. 5 0. Sp gr. 4.21. Translucent, opaque. Colour reddish-brown. Streak pale.

Found in Norway and Siberia.

MAGNESIA.

Borate of Magnesia.

a. BORACITE, No. 425.

Haüy, 2.56. Phil. 181. Haid. 2.347. Leon. 287.

Occurs in imbedded crystals.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the octahedron, very indistinct. Fracture uneven, imperfectly conchoidal. Hard. 7.0. Sp.gr. 2.97. Transparent, translucent. Lustre vitreous. Colour greyish, yellowish, and greenish-white. Streak white.

Found only at Segeberg in Holstein, and Lüneburg in Brunswick.

Carbonate of Magnesia.

a. MAGNESITE, No. 466.

Phil. 179. Haid. 3.121. Leon. 302.

Occurs in acicular crystals, massive, and in powder. Colour generally white, occasionally greyish and yellowish.

The *massive varieties* are found in nodular and stalactitic forms and amorphous. Fracture, hardness, and specific gravity variable, according as the Mineral is more or less compact or earthy.

Found in several parts of Europe, in India, and abundantly at Hoboken in North America.

Carbonate of Magnesia and Iron.

a. BREUNNERIT, No. 450.

Phil. 378. Haid. 2.99. Leon. 309.

Occurs in imbedded crystals.

Primary form a Rhomboid. CRYST. fig. 106. P,P′= 107° 30′. Cleavage parallel to the primary planes, very distinct. Fracture conchoidal. Hard. 4.0, 4.5. Sp.gr. 3.0, 3.2. Transparent, translucent. Lustre vitreous. Colour yellow, of different shades, and black. Streak white.

Found at Zillerthal and other places in Salzburg, and in the Tyrol.

Hydrate of Magnesia.

a. SHEPARDITE, No. 141.

Phil. 95. Haid. 3.112. Leon. 244.

Occurs rarely in attached or imbedded hexagonal prisms, generally in laminar masses and fibrous.

Primary form a Rhomboid. CRYST. fig. 106. P,P′,

unknown. Hard. 1.0, 1.5. Sp.gr. 2.33, 2.63. Transparent, translucent. Lustre pearly. Colour white, greenish-white. Streak white.

The fibrous variety is the *Nemalite* of Nuttall.

Found at Hoboken in New Jersey, North America, and in the Isle of Unst, Shetland.

Phosphate of Magnesia.

a. WAGNERIT, No. 486.

Haid. 3.169. Leon. 277. P.M. and An. 1.133.

Occurs in attached or imbedded crystals.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 109° 20′. M,M′ = 95° 25′. Cleavage indistinct, parallel to the horizontal diagonal. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 3.01. Transparent, translucent. Lustre vitreous. Colour greyish and reddish-yellow. Streak white.

Found at Hollgraben in Salzburg, and is said to have occurred in the United States.

Silicate of Magnesia.

a. MARMOLITE, No. 167.

Haid. 3.124. Leon. 762.

Occurs massive; structure columnar, irregularly intersecting. The columnar portions are foliated, having a cleavage in two directions intersecting each other. Hard. 3.5. Sp.gr. 2.47. Translucent. Opaque. Lustre pearly. Colour pale yellowish and greyish-green

Found at Hoboken in New Jersey, North America.

It is probable that the serpentines are also silicates of magnesia, and for the present we include them in this class

b. SERPENTINE, No. 163.

Phil. 97. Haid. 3.151. Leon. 777

Occurs in imbedded crystals and massive. Fracture conchoidal, uneven, splintery. Hard. 3.0. Sp.gr. 2.2, 2.6. Nearly opaque. Lustre resinous, dull. Colour dull greenish-yellow, and various shades of green, sometimes very dark and spotted with red. Streak white, shining.

Found in all parts of the World in beds and mountain masses.

The *Steatoid* of Möller, E.J.S. N.S. 3.31, occurs in crystals at Snarum in Norway, and is said to be a variety of serpentine.

c. STEATITE. *Soap Stone. Speckstein. Talc Steatite*, No. 164.

Haüy, 2.493. Phil. 118. Haid. 3.157. Leon. 188, 223.

Occurs in amorphous masses, sometimes containing imbedded crystals of the same substance, of the forms of quartz and carbonate of lime. Structure compact. Fracture uneven, splintery. Soft. Sp.gr. 2.6, 2.63. Opaque. Dull. Colour yellowish and greyish-white. Streak shining. Feels greasy.

Said to be found in many parts of the World, but it is probable that several distinct Minerals, merely on account of their soapy or greasy feel, have been so named.

d. MEERSCHAUM, No. 165

Phil. 180. Leon. 222.

Occurs in imbedded masses. Structure earthy. Fracture uneven. Opaque. Dull. Colour white, sometimes slightly yellowish or greyish. Streak white.

Found in Greece, the Crimea, and some other parts of Europe.

Sulphate of Magnesia.

a. EPSOMITE. *Epsom Salt*, No. 535.

Haüy, 2.51. Phil. 180. Haid. 2.48. Leon. 116.

Occurs botryoidal, reniform, massive, as a crust on the surface of other bodies, and in solution in Mineral waters. Structure fibrous, sometimes earthy. Fracture, when observable, conchoidal. Hard. of artificial crystals 2.0, 2.5. Sp.gr. 1.75. Transparent, translucent. Lustre vitreous. Colour white. Streak white.

Found on the surface of decomposing schist, in coal pits, on old walls, and in other situations.

Sulphate of Magnesia and Soda.

a. BLOEDITE, No. 537.

Haid. 3.79. Leon. 125.

Occurs in fibrous masses, accompanying the Polyhallite at Ischel in Upper Austria. Fracture uneven. Translucent. Lustre nearly vitreous. Colour red.

MANGANESE.

ARSENIURET OF MANGANESE? No. 39.

Inst. J. 1829, 2.381.

Occurs on foliated galena. Structure fine granular. Fracture uneven. Brittle. Sp.gr. 5.55. Opaque. Lustre metallic. Colour whitish-grey, but becoming dull and covered with a fine blackish powder after exposure to the air.

Supposed to have been found in Saxony.

Carbonate of Manganese.

a. KÖHLERITE, No. 451.

Phil. 246. Haid. 2.106. Leon. 299.

Occurs in attached crystals and massive.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ about 107°. Cleavage parallel to the primary planes. Fracture uneven Hard. 3.5. Sp.gr. 3.59. Translucent. Lustre vitreous, on cleavage surfaces rather pearly. Colour rose-red, sometimes brownish. Streak white.

Massive varieties, globular, botryoidal. Structure fibrous, compact. Amorphous, structure granular, fibrous, compact.

Found at Kapnic and Nagyak in Transylvania, and in Saxony, the Hartz, and other places.

Oxide of Manganese.

a. MANGANITE, No. 118.

E.J.S. 4.41.

Occurs in attached and imbedded crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 99° 30′. Cleavage parallel to the lateral planes and both diagonals. Fracture uneven. Hard. 4.0, 4.25. Sp.gr. 4.32. Opaque. Lustre imperfect metallic. Colour dark brownish or greyish-black. Streak reddish-brown.

Massive varieties, amorphous. Structure crystalline, granular, large fibrous.

Found at Ilefeld in the Hartz, and in other places.

b. VARVICITE, No. 119.

P.M. and An. 5.209.

Occurs massive, and resembles Manganite in colour, but is much softer, and soils the fingers more. Sp.gr. 4.819.

Found in Warwickshire.

c. PYROLUSITE, No. 120.

E.J.S. 9.304.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ about 93° 40′. Levy. Cleavage parallel to the lateral planes and short diagonal, indistinct. Hard. 2.0, 2.5. Sp.gr. 4.82, 4.94. Opaque. Lustre metallic. Colour iron-black. Streak black.

Massive varieties, reniform, botryoidal, amorphous. Structure fibrous, granular.

Found in Thuringia and many other places in Europe, and in Brazil, *but never at Ilefeld*, with the Manganite.

d. PSILOMELANE, No. 121.

E.J.S. 4.47.

Occurs in reniform, botryoidal, and fruticose shapes, and amorphous. Structure indistinctly fibrous and granular, compact. Fracture conchoidal, even. Hard. 5.0, 6.0. Sp.gr. 4.145. Opaque. Lustre imperfect metallic. Colour bluish and greyish-black. Streak brownish-black.

Found in most depositories of manganese ores.

e. HAUSMANNITE, No. 122.

E.J S. 4.46.

Occurs in attached octahedral crystals, and massive.

Primary form a Square prism. CRYST. fig. 61. *c,c′*, fig. 64, = 105° 25′. Cleavage parallel to P,C, and *a*, fig. 62. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 4.722. Opaque. Lustre imperfect metallic. Colour brownish-black.

Found at Ilmenau in Thuringia.

f. BRAUNITE, No. 123.

E.J.S. 4.48.

Occurs in attached and imbedded crystals and massive. Primary form a Square prism. CRYST. fig. 64. c,c′, fig. 67, = 109° 53′. Cleavage parallel to c, distinct. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 4.818. Opaque. Lustre imperfect metallic. Colour dark brownish-black. Streak the same.

Found at Elgersburg and at Wunsiadel, and perhaps in Thuringia.

Oxide of Manganese, Iron, and Copper.

a. BLACK COPPER. *Black Oxide of Copper*, No. 132.

Leon. 564.

Occurs in amorphous masses. Structure earthy. Soft, friable. Opaque. Dull. Colour black.

Found in most copper mines.

Oxide of Manganese and Copper.

a. CUPREOUS MANGANESE, No. 133.

Haid. 3.92. Leon. 755.

Occurs reniform, botryoidal, and amorphous. Structure compact. Fracture imperfect conchoidal. Sp.gr. 3.197, 3.216. Opaque. Lustre resinous. Colour bluish-black. Streak the same.

Found in Bohemia and ? in Chili.

Phosphate of Manganese and Iron.

a. ULLMANNITE, No. 490.

Phil. 248. Haid. 3.136. Leon. 284.

Occurs massive. Cleavage in three directions perpendicular to each other. Fracture flat conchoidal. Hard. 5.0, 5.5. Sp.gr. 3.44, 3.77. Opaquo. Lustre resinous. Colour reddish or brownish-black. Streak yellowish-grey.

Found near Limoges in France, and ? near Pennsylvania, North America.

b. HETEPOZITE, No. 491.

E.J.S. N.S. 3.359.

Occurs in scaly masses. Cleavage in three directions, giving an Oblique rhombic prism of about 100°. Hard. about 5. Sp.gr. 3.524. Lustre resinous. Colour greenish or bluish-grey.

Found near Limoges.

c. HURAULITE, No. 492.

E.J.S. N.S. 3.359.

Bi-silicate of Manganese.

a. STRÖMITE, No. 169.

Occurs in minute crystals. Hard. about 4.0. Sp.gr. 2.27. Transparent. Lustre vitreous. Colour reddish-yellow.

Found near Limoges.

Phil. 245. Haid. 3.122. Leon. 520.

Occurs massive. Structure crystalline. Cleavage parallel to the lateral planes of a prism of about 92° 30′, and to both its diagonals. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 3.54. Slightly translucent. Colour red.

Found in Sweden, and at Franklin in New Jersey, North America.

Compounds of silica, oxide of manganese, and carbonate of manganese have been indistinctly described under the names of Allagite, Rhodonite, Photizite, and Hornmangan, but whether they are distinct species may perhaps be questioned. Specimens have appeared in this Country under these names, but little resembling in their characters the published descriptions.

Sulphuret of Manganese.

a. KOBELLITE, No. 70.

Haüy, 4.268. Phil. 246. Haid. 3.31. Leon. 656.

Primary form a Cube. CRYST. fig. 51. Cleavage parallel to P, distinct. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 4.014. Opaque. Lustre imperfect metallic. Colour, when first fractured, dark steel-grey, but becomes greyish-black by exposure to the air. Streak dark green.

Massive varieties, amorphous, structure granular, compact.

Found at Nagyag in Transylvania, and ? in Cornwall.

MELLILITE, No. 361.

Haüy, 4.504. Phil. 208. Haid. 3.125. Leon. 213, 760.

Occurs in attached crystals.

Primary form a Square prism. CRYST. fig. 65. Translucent, opaque. Colour reddish and greyish-yellow, and brownish-red.

Found at Tivoli and Capo di Bove near Rome.

MERCURY.

Chloride of Mercury.

BAUMERITE. *Horn Mercury. Muriate of Mercury*, No. 68.

Haüy, 3.331. Phil. 359. Haid. 2.156. Leon. 580

Occurs in attached crystals, and in tubercular crusts.

Primary form a Square prism. CRYST. fig. 65. Cleavage parallel to the lateral planes. Fracture conchoidal. Hard. 1.0, 2.0. Sp.gr. 6.482. Translucent. Lustre adamantine. Colour yellowish or pale grey. Streak white.

Found with other ores of Mercury in Bohemia, the Palatinate, Spain, and principally at Moschel-andsberg, in Deuxponts.

Native Mercury.

a. MERCURY, No. 12.

Haüy, 3.297. Phil. 357. Haid. 2.432. Leon. 696.

Fluid. Occurs in small cavities or crevices of the rock in which it is found, and is frequently accom-

panied by red silver. Sp.gr. 13.6. Opaque. Lustre bright metallic. Colour tin-white.

Its principal localities are Idria in Carniola, and Almaden in Spain.

b. NATIVE AMALGAM, No. 13.

Haüy, 3.297. Phil. 357. Haid. 2.431. Leon. 698.

Occurs in attached and imbedded crystals, and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage flat conchoidal, very indistinct. Hard. 3.0. 3.5. Sp.gr. 13.755. Opaque. Lustre bright metallic. Colour silver white. Streak the same.

Massive variety, amorphous. Structure compact. It is sometimes rendered semi-fluid by mixture with fluid mercury.

Found in Hungary, the Palatinate, Deuxponts, and in France, Spain, and Sweden.

Sulphuret of Mercury.

a. CINNABAR. *Hepatic Cinnabar. Liverore*, No. 92.

Haüy, 3.313. Phil. 358. Haid. 3.44. Leon. 631.

Occurs in attached crystals and massive.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 71° 48′. Cleavage distinct, parallel to plane *e*, fig. 111. Fracture conchoidal. Hard. 2.0, 2,5. Sp.gr. 8.1. Transparent, translucent. Lustre adamantine. Colour bright red, and darker shades to reddish-grey. Streak scarlet.

Massive varieties, amorphous. Structure granular to compact, sometimes fibrous and pulverulent.

The *Hepatic* and *Bituminous Cinnabar* appear to be mixtures of this ore with shale and coarse coal.

Found in Europe, chiefly at Idria in Carniola, at Almaden in Spain, and in the Palatinate, and in several parts of Mexico and South America.

MESOLE, No. 209.

Haid. 3.126. Leon. 206.

Occurs in globular and reniform masses, sometimes imbedded, but generally covering a thin stratum of Mesoline. Structure fibrous, foliated, radiating. Hard. 3.5. Sp gr. 2.37. Translucent. Lustre pearly. Colour white, sometimes yellowish.

Found in the Faroe Islands.

MESOTYPE. *Natrolite*, No. 207.

Haüy, 3.179. Phil. 123. Haid. 2.236. Leon. 204.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 91° 10′. Cleavage parallel to the lateral planes. Fracture conchoidal. Hard. 5.0, 5.5. Sp.gr. 2.249. Transparent, translucent. Lustre vitreous. Colour white, with shades of grey, red, and yellow. Streak white.

Massive varieties, globular and reniform. Structure fibrous, radiating. Surface drusy.

Found in Iceland, the Faroe Islands, Scotland, Ireland, and in many other places, lining cavities in basaltic and porphyritic rocks and ancient lavas.

MESOLITE. *Needle Stone*, No. 208.

Corresponds nearly with the preceding description, but the angle of the prism is 91° 20′.

MICA.

It is certain that several distinct species of Minerals are included under this name, merely because they may be easily split into *very thin, shining* plates, but they cannot at present be distinguished by any characters which have been hitherto given. The following description of crystalline forms applies principally to the micas from Vesuvius.

a. *Rhomboidal*, No. 258.

Haüy, 3.111. Phil. 106. Haid. 2.198. Leon. 437.

Occurs in attached hexagonal prisms, and massive.

Primary form a Rhomboid. CRYST. fig. 106. Cleavage very distinct, perpendicular to the axis. Fracture not observable. Hardness of the cleavage surfaces 2.0. 2.5, that of the edges being 4.5, 5.5. Sp.gr. 2.7, 3.0. Transparent, translucent. Lustre vitreous, pearly on the cleavage surfaces. Colour white, grey, black, brown, pale red, dull yellow, green. Streak white, grey.

Massive varieties, globular, structure fibrous, foliated. Amorphous, structure foliated, granular, fibrous.

Found in primitive rocks in all parts of the World, and abundantly in the masses ejected from Vesuvius.

b. *Oblique prismatic*, No. 259.

The preceding references and descriptions will probably apply to this variety, with the exception of the crystalline form, which is an Oblique rhombic prism. CRYST. fig. 83. P,M = 98° 40′. M,M′ = 120°. Phil.

c. LEPIDOLITE. *Lilac Mica*, No. 260.

Haüy, 3.116. Phil. 141. Haid. 2.202. Leon. 451.

Occurs in amorphous masses, composed generally of small, thin, flexible scales. Fracture uneven. Sp.gr. 2.832. The scales or plates are translucent. Colour pearl-grey, rose and purple-red, and greenish.

Found at Rozena in Moravia, at Utö in Sweden, in North America, and some few other places.

d. MARGARITE. *Pearl Mica*, No. 261.

Phil. 208. Haid. 2.204. Leon. 766.

Occurs in thin, hexagonal, attached crystals, and in masses of small, thin, shining laminæ.

Primary form a Rhomboid. CRYST. fig. 56. Cleavage distinct, perpendicular to the axis. Fracture not observable. Hard. 3.5, 4.5. Sp.gr. 3.032. Translucent. Lustre pearly, bright. Colour greyish, reddish, and yellowish-white. Streak white.

Found at Sterzing in the Tyrol.

e. RUBELLAN. *Red Mica?* No. 262.

Leon. 774.

Occurs in small, imbedded, hexagonal, micaceous plates, not elastic. Soft. Sp.gr. 2.5, 2.7. Colour reddish-brown.

f. ODERIT. *Black Mica?* No. 263.

Occurs in masses which may be split into thin leaves like mica. It is opaque and black, with very little lustre, and is probably mica, containing some foreign matter, which has altered its usual appearance.

Found in Sweden.

MOLYBDENUM.

Sulphuret of Molybdenum.

a. MOLYBDENITE, No. 107.

Haüy, 4.326. Phil. 248. Haid. 3.18. Leon. 667.

Occurs in imbedded hexagonal crystals, and massive.

Primary form a Rhomboid. Cleavage very distinct, perpendicular to the axis. Fracture not observable. Hard. 1.0, 1.5. Sp.gr. 4.5, 4.7. Opaque. Lustre metallic. Colour lead-grey. Streak the same. Thin laminæ very flexible.

Massive variety, amorphous, structure granular, foliated.

Found in Saxony and Bohemia, and in other places in Europe and America.

OXIDE OF MOLYBDENUM, No. 416.
Phil. 249.
Occurs as a crust on the sulphuret, and in thin layers between its laminæ. Structure earthy, and very thin fibrous. Friable. Dull. Colour pale yellow.
Found in Norway, Scotland, and North America. Has not been analyzed.

MONTICELLITE, No. 362.
P.M. and An. 10.265.
A Mineral from Vesuvius, nearly resembling Peridot in its form and measurements, but requiring further examination of better specimens for the purpose of a more exact description.

MURCHISONITE, No. 363.
P.M. and An. 1.448.
Occurs in imbedded crystals and crystalline masses.
Primary form an Oblique rhombic prism. CRYST. fig. 83. P,*h*, fig. 91 = 106° 50′. Cleavage distinct parallel to P and to both its diagonals. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 2.509. Translucent, opaque. Lustre vitreous, pearly on the plane *h*. Colour white, with a slight tinge of red.
Found imbedded in the new red sandstone at Dawlish, and at Heavitree, near Exeter, Devonshire.
The inclination of P on *h* agrees very nearly, if not exactly, with the measurement on corresponding planes of the *moon-stone* of Ceylon, the peculiar lustre of which is observable, as in Murchisonite, only on the plane *h*.

MURIATIC ACID GAS, *Chlorine*, No. 58.
Occurs in the state of gas. Transparent. Sp.gr. 1.274. Odour pungent. Taste acid.
Found in the neighbourhood of active volcanoes.

NECRONITE, No. 364.
Appears from its cleavage, hardness, and some other characters to be felspar.

NEPHELINE. *Sommite*, No. 239.
Haüy, 3.347. Phil. 125. Haid. 2.250. Leon. 468.
Occurs in attached hexagonal prisms. Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 88° 55′. Haid. Cleavage *indistinct*, parallel to the planes of the hexagonal prism. Fracture conchoidal. Hard. 6.0. Sp.gr. 2.56. Transparent, translucent. Lustre vitreous. Colour white. Streak white.
Found among the matter ejected from Vesuvius.

Nickel.

ARSENIATE OF NICKEL, No. 474.
Haüy, 3.421. Phil. 284. Haid. 2.448. Leon. 164.
Occurs as a powdery crust on the surface of arseniuret of nickel, and massive. Opaque. Dull. Colour green, and greenish-white.
Found accompanying arseniuret of nickel, and produced from the decomposition of that substance.

Arseniuret of Nickel.

COPPER NICKEL, No. 28.
Haüy, 3.417. Phil. 283. Haid. 2.446. Leon. 678.
Occurs in botryoidal and reniform masses, with a fibrous structure; more commonly amorphous. Structure compact. Fracture uneven. Splintery. Hard. 5.0, 5.5. Sp.gr. 7.65. Opaque. Lustre metallic. Colour yellowish and greyish-red of different shades. Streak pale brownish-black.
Found in Cornwall, Scotland, Saxony, Bohemia, and other parts of Europe, and in South America.

OXIDE OF NICKEL, No. 130.
Phil. 284.
Occurs in a green Mineral named Pimelite, but whether combined with silica, or merely colouring hydrous quartz, appears uncertain.
Found in Serpentine in Silesia.

Sulphuret of Nickel.

NATIVE NICKEL. *Capillary Nickel*, No. 76.
Haüy, 3.412. Phil. 282. Haid. 3.129. Leon. 651.
Occurs in regular hexagonal capillary crystals.
Primary form a Rhomboid. CRYST. fig. 106. Opaque. Lustre metallic. Colour yellow, sometimes greyish.
Found in Wales and Cornwall in England, and in Saxony, Bohemia, and the Hartz.

Sulpho-arseniuret of Nickel.

NICKELGLANZ. *Grey Nickel*, No. 115.
An. 15.147. Leon. 652
Occurs massive. Structure granular. Fracture of the mass uneven, the separate grains foliated. Easily frangible. Sp.gr. 6.129. Opaque. Lustre metallic. Colour pale lead-grey, becoming reddish by tarnish.
Found in Sweden and in the Hartz.

NUTTALLITE, No. 365.
Haid. 3.133. Leon. 765.
Occurs in attached and imbedded crystals.
Primary form a Square prism. CRYST. fig. 65, of the same dimensions as Scapolite. Cleavage parallel to the lateral planes. Fracture uneven. Hard. 4.0, 4.5. Translucent. Lustre vitreous. Colour grey.
Found at Bolton in Massachusetts. And probably some of the dark grey Scapolites from Finland will be found to belong to this species.

OBSIDIAN. *Marckanite*, No. 249.
Haüy, 3.101. Phil. 112. Haid. 2.337. Leon. 413.
Occurs massive and in rolled grains. Structure compact. Fracture conchoidal. Hard. 6.0, 7.0. Sp.gr. 2.35, 2.40. Transparent, opaque. Lustre vitreous. Colour greyish-brown, greenish or brownish-black, black, dull red, and dull green.
Found in the neighbourhood of most volcanoes, and in beds and veins traversing rocks in many parts of Europe, Asia, and America.
Obsidian, Pitchstone, Pearlstone, and Pumice have been considered as belonging to the same Mineral species, from the apparent passage of one into the other, and the consequent absence of exact characters by which they may be distinguished. There appears, however, a chemical difference in their composition; the Pitchstone and Pearlstone containing water, which the others do not; on which account they have been kept separate in this Treatise.

OSMELITE, No. 366.
P.M. and An. 3.71.
Is said to consist of thin prismatic concretions, either scopiformly or stellularly arranged, and these again collected into masses of coarse, granular concretions. Cleavage apparent in only one direction. Hard. 4.0, 5.0. Sp.gr. about 2.8. Translucent. Colour whitish, yellowish, and brownish-grey. Feels greasy. Odour strong clayey. Taste like clay, and seems to dissolve in the mouth, but without producing any apparent change in the substance.
Found at Niederkirchen, near Wolfstein, on the Rhine.

OSMIUM, a metal found combined with Iridium, in small

grains among the platina in South America and Russia. See IRIDIUM.

OSTRANITE, No. 367.
E.N.P.J. 4.186. Leon. 765.
Is said to occur crystallized in the form of a Right rhombic prism, of about 96°. Hard. about 6.5. Sp.gr. 4.32. Lustre vitreous. Colour dark brown.
Found in Norway, and supposed by M. Breithaupt to be a new metallic oxide.

PALLADIUM, No. 14.
Haüy, 3.230. Phil. 325. Haid. 3.134. Leon.
Occurs in rolled grains accompanying the native platina of Brazil, and in minute particles, imbedded in and combined with much of the native gold of Brazil.
Structure of the rolled grains fibrous, divergent. Sp.gr. 11.8. Opaque. Lustre metallic. Colour whitish steel-grey.

PEARLSTONE, No. 245.
Phil. 112. Haid. 2.337. Leon. 182.
Occurs massive. Structure granular, the grains varying in size, and formed of thin concentric laminæ. Fracture uneven. Hard. 4.5, 5.0. Sp.gr. 2.34. Translucent, opaque. Lustre pearly. Colour grey, greyish-black, blackish or reddish-brown.
Found principally at Tokay, in Hungary, also at Cabo da Gato, in Spain, and in a few other places.
See OBSIDIAN.

PEKTOLITE, No. 225.
E.J.S. 9.364.
Occurs in spheroidal masses. Structure fibrous, radiating. Hard. 4.5, 5.5. Sp.gr. 2.69. Nearly opaque. Lustre pearly. Colour greyish-white.
Found on Natrolite at Monte Baldo, South Tyrol.

PERIDOT. *Chrysolite. Olivine? Hyalosiderite?* No. 283.
Haüy, 2.465. Phil. 95. 96. Haid. 2.345. Leon. 530.
Occurs in attached, imbedded, and loose crystals, and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 120°. Levy. Fracture conchoidal. Hard. 6.5, 7.0. Sp.gr. 3.441. Transparent, translucent. Lustre vitreous. Colour green of various shades, sometimes yellowish or brownish. Streak white.
Massive varieties, amorphous. Composition granular, the grains slightly coherent.
The locality of the Chrysolite used in jewellery is not known, but is supposed to be Upper Egypt. Olivine occurs in basalt and lava in Bohemia, Hungary, on the banks of the Rhine, and in other places.

PETALITE, No. 229.
Haüy, 3.137. Phil. 143. Haid. 2.248. Leon. 416.
Occurs in masses composed of smaller crystalline masses, promiscuously aggregated, sometimes so minute as to appear compact. Cleavage parallel to the lateral planes and both diagonals of a rhombic prism of about 100°. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 2.44. Translucent. Lustre vitreous. Colour white. Streak white.
Found at Utön in Sweden, and in North America.

PICROLITE, No. 251.
Phil. 209. Haid. 3.136. Leon. 225.
Occurs massive. Structure thin fibrous. Fracture splintery. Hard. 3.0, 6.0. Nearly opaque. Little lustre, inclining to pearly. Colour yellowish-green.
Found at Taberg and Nordmarken in Sweden.

PICROSMINE, No. 252.
Haid. 3.137. Leon. 512, 768.
Occurs crystallized and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 117° 49′. Cleavage distinct parallel to P, indistinct parallel to the long diagonal and to M. Fracture indistinct, uneven. Hard. 2.5, 3.0. Sp.gr. 2.66. Nearly opaque. Lustre dull vitreous, pearly on the surface M. Colour greenish-white, green of several shades, sometimes blackish. Streak white.
Massive varieties: structure thin fibrous, fracture splintery; granular to compact, fracture earthy.
Found at Engelsburg in Bohemia.

PINITE, No. 266.
Haüy, 2.353. Phil. 80. Haid. 3 139. Leon. 464.
Occurs in imbedded crystals, which are generally hexagonal prisms.
Primary form a Rhomboid. CRYST. fig. 106. P,P′ unknown. Cleavage very indistinct. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 2.78, 2.98. Opaque. Lustre slightly resinous. Colour greenish-grey, blackish-brown, brown, blackish-green.
Found in Saxony, Auvergne, England, and some other parts of Europe, and in North America.

PINGUITE, No. 368.
E.N.P.J. 9.382. Leon. 468.
Occurs massive at Beschert-Gluck, Saxony, and is said to resemble Bole and Green iron earth; two names under which several substances differing in most of their characters appear to have been classed. Hence they afford little indication of the characters of Pinguite.

PITCHSTONE, No. 246.
Phil. 130. Haid. 2.337. Leon. 181.
Occurs massive. Structure compact, sometimes slaty. Fracture imperfect conchoidal, one of the characters by which it is distinguished from Obsidian. Hard. 5.0, 6.0. Sp.gr. 2.3, 2.7. Translucent, opaque. Lustre resino-vitreous. Colour grey, black, brown, red, yellow, green, blue, dull and sometimes variously mixed.
Found at Meissner in Saxony, in Ireland, the Western Islands of Scotland, and in other places.
See OBSIDIAN.

PLATINA, No. 15.
Haüy, 3.226. Phil. 324. Haid. 2.441. Leon. 705.
Occurs in grains of various sizes. No cleavage. Fracture hackly. Hard. 4.0, 4.5. Sp.gr. 17.332. Opaque. Lustre metallic. Colour steel-grey. Streak shining.
Found in Peru, Brazil, and lately in Russia.

PLURANIUM, P.M. and An. 2.391, 5.234.
A metal said to have been discovered in the Russian Platina by Professor Osann of Dorpat.

POLYHALLITE, No. 538.
Phil. 199. Haid. 3.141. Leon. 769. E.J.S. 7.246.
Occurs crystallized and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = about 115°. Cleavage indistinct, parallel to M,M′. Fracture uneven. Hard. 2.5. Sp.gr. 2.73, 2.77. Opaque. Lustre resinous. Colour pale flesh-red, sometimes yellowish.
Found at Ischel in Upper Austria.

POONAHLITE, No. 369.
P.M. and An. 10.109.
Occurs in long slender crystals accompanying Apophyllite and Stilbite.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 92° 20′. Fracture uneven. Transparent, translucent. Lustre vitreous. Colourless, white.

Found at Poonah in the East Indies.

POTASH.

Nitrate of Potash.

a. NITRE. *Saltpetre*, No. 517.

Haüy, 2.177. Phil. 189. Haid. 2.34. Leon. 247.

Occurs in crusts and capillary fibres, on or near the surface of the earth, and in old walls, &c. Hard. 2.0. Sp.gr. 1.93. Transparent, translucent. Lustre of the fractured surface vitreous. Colour white, sometimes yellowish. Taste saline and cool.

Found in most parts of the World.

Sulphate of Potash.

a. BERNHARDITE, No. 524.

Haüy, 2.187. Haid. 3.159. Leon. 271.

Occurs at Mount Vesuvius in small white tubercular or globular masses on lava. Hard. 2.5, 3.0. Sp.gr. 1.737. Translucent. Lustre of the fractured surface vitreous.

PREHNITE, No. 222.

Koupholite when in very thin crystals.

Haüy, 2.603. Phil. 36. Haid. 2.217. Leon. 470.

Occurs in attached and aggregated crystals and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 99° 50′. Cleavage distinct, parallel to P, less so parallel to the lateral planes. Fracture uneven. Hard. 6.0, 7.0. Sp.gr. 2.926. Transparent, translucent. Lustre vitreous. Colour white, grey, yellow, green of various shades. Streak white.

Massive varieties, globular, botryoidal, nodular, stalactitic. Structure broad fibrous. Amorphous, structure granular, compact. Surfaces rough, drusy.

Found originally at the Cape of Good Hope, and since at many places in Europe, America, and Asia.

PUMICE, No. 247.

Phil. 133. Haid. 2.337. Leon. 411.

Occurs massive. Structure fibrous, and very porous. From its porous structure it floats on water. Translucent, opaque. Lustre of some varieties vitreous, but generally pearly. Colour grey, sometimes brownish or yellowish.

Found principally in the Lipari Islands.

See OBSIDIAN.

PYRALLOLITE, No. 166.

Phil. 68. Haid. 3.141. Leon. 512.

Occurs crystallized and massive. Cleavage parallel to the lateral planes of a prism of about 94° 36′. Fracture earthy. Hard. 3.5, 4.0. Sp.gr. 2.55, 2.60. Translucent, opaque. Lustre resinous. Colour white, occasionally greenish or yellowish.

Massive variety, structure fibrous, granular.

Found at Pargas in Finland.

PYRARGILLITE, No. 370.

Occurs in bluish and brownish-black amorphous masses, in a felspar or granitic rock in Finland.

PYROPHYLLITE, No. 255.

Formerly known as *Radiated Talc*, but newly named on account of its ready exfoliation on exposure to heat.

PYROSMALITE, No. 282.

Phil. 235. Haid. 3.143. Leon. 772.

Occurs in attached and imbedded hexagonal prisms.

Primary form a Rhomboid. CRYST. fig. 106. Cleavage distinct perpendicular to the axis, indistinct parallel to the planes of the prism. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 3.08. Transparent, opaque. Lustre of the transparent variety, vitreous, of the opaque, pearly on the cleavage surface. Colour greyish-green. Streak pale.

Found at Nordmark in Sweden.

PYROXENE. *Alalite. Baikalite. Diopside. Fassaite. Malacolite. Mussite. Pyrgom. Sahlite*, No. 268 to 272.

Haüy, 2.407. Phil. 58. Haid. 2.268. Leon. 503.

Occurs in attached and imbedded crystals and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 105° 45′. M,M′ = 87° 5′. Cleavage parallel to the lateral planes and to both the diagonals. Fracture conchoidal, uneven. Hard. 5.0, 6.0. Sp.gr. 3.23, 3.35. Transparent to opaque. Lustre vitreous, vitreo-resinous. Colour white, grey, black, brown, yellow, green, of many shades. Streak paler colour.

Massive varieties, amorphous. Structure granular, columnar, parallel, and radiating; laminar.

Found in most basaltic rocks, in lava, and in the older rocks in most parts of the World.

RADIOLITE? No. 224.

E.J.S. 10.370.

The notice referred to is that of an analysis by Hunefeld of a substance called Radiolite, unaccompanied by any description or indication of locality. A specimen in the writer's possession, so named we believe by Esmark, exactly resembles the fibrous Mineral from Norway named *Bergmannite*. But whether this is the Mineral analyzed by Hunefeld is uncertain.

RAZOUMOFFSKIN, No. 371.

An. 4.215. 7.62.

A white powder discovered by Lentz in the clefts of quartz rocks in Silesia. In vol. iv. of the *Annals of Phil.* it is said to be composed of *silica, alumina, potash and water*; and in vol. vii. it is said to contain *silica, magnesia, and carbonic acid.* Hence two different Minerals have passed under this name.

RHODIUM. A brittle metal found by Dr. Wollaston in combination with native platina as an alloy.

RHUTENIUM. P.M. and An. 2.391. 5.233.

A metal said to have been discovered in the Russian platina by Professor Osann of Dorpat.

SAPHIRINE, No. 313.

Leon. 775.

Occurs in thin crystalline plates, separated by plates of mica. Fracture uneven. Hard. 7.0, 8.0. Sp.gr. 3.42. Translucent. Lustre vitreous. Colour blue, sometimes greenish. Streak white.

Found in Greenland.

SARCOLITE, No. 372.

P.M. and An. 10.189.

Occurs in attached crystals.

Primary form a Square prism. CRYST. fig. 61. Trans-

parent, translucent. Lustre vitreous. Colour white, and pale flesh-red.

Found in cavities in the masses ejected from Vesuvius.

Red *Analcime* and *Gmelinite* have incorrectly passed under this name merely on account of their colour.

SCAPOLITE. *Paranthine. Wernerite. Chelmsfordite,* No. 235.

Haüy, 2.586. Phil. 137. Haid. 2.264. Leon. 474.

Occurs in attached and imbedded crystals and mas-

Primary form a Square prism. CRYST. fig. 61. Frequently decomposed and dull on the surface. Cleavage parallel to the primary planes and both the diagonals. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.72. Translucent, opaque. Lustre vitreous. Colour white, grey, green, red.

Found in Norway, Sweden, Finland, Greenland, and in North America.

Meionite, No. 236. Generally in transparent crystals from Vesuvius.

SCHEELIUM.

a. OXIDE OF SCHEELIUM. *Scheelic Acid? Tungstic Acid?* No. 412.

Phil. 254.

Occurs massive, with some appearance of crystalline form. Fracture conchoidal. Sp.gr. 6.0. Translucent. Lustre adamantine. Colour yellow of different shades, sometimes greyish. Resembles sulphur in appearance. Inodorous. Tasteless. Insoluble in acids.

Found in quartz in a mine near Baltimore? North America.

SCHILLER SPAR. *Diallage Metalloide.* No. 287.

Haüy, 2.455. Phil. 71. Haid. 2.206. Leon. 517.

Occurs in crystalline plates and small aggregated crystals generally in serpentine. Cleavage parallel to the lateral planes and to both the diagonals of a rhombic prism of about 93° 30′. The angle of 135° to 140° quoted by Haidinger is evidently the inclination of a *primary* to a *diagonal* plane, which is 136° 15′. Fracture uneven, scarcely observable. Hard. 3.5, 4.0. Sp.gr. 2.69. Nearly opaque. Lustre pearly metallic. Colour yellowish and blackish green.

Found at Baste in the Hartz, at Zöbliz in Saxony, and a few other places.

SCHOARITE, No. 529.

Leon. 258.

This Mineral is said to be fibrous, and composed of 10 parts of silex and 90 of sulphate of barytes, *and to be soluble in sulphuric acid.*

Its professed locality is Carlisle, in the State of New York, North America.

SELENIUM, No. 45.

Occurs as a red coating on sulphur, and sometimes in small globular and botryoidal shapes, with a smooth and bright surface. Fracture conchoidal. Translucent. Lustre vitreous. Colour pale dull red.

Found in the Lipari Islands.

SIDEROCLEPTE, No. 373.

Gal. 273.

Soft. Translucent. Lustre greasy. Colour yellowish-green.

Found in the lavas of the extinct volcanoes of Brisgau.

SULPHURET OF SELENIUM, No. 110.

E.P.J. 13.190. Leon. 599.

Found in the Lipari Islands, disposed in layers, and of a brownish-yellow colour.

SILICA.

Haüy, 2.228. Phil. 1. Haid. 2.321. Leon. 372.

The differences of structure, hardness, specific gravity, mixture with foreign matter, and other characters belonging to this species, are so numerous as to render any single description inapplicable to all its varieties. And the intimate connection of some of these with others, into which they appear to pass by insensible degrees, as that of brittle opal into tough calcedony, renders it equally impracticable to define with precision their respective limits. It will, however, be convenient to divide the species first into *anhydrous*, which we simply term *quartz*, and *hydrous quartz;* and each of these into smaller subdivisions.

QUARTZ, No. 154.

a. The structure crystalline.

1. *Attached, imbedded, and aggregated crystals.*

Colourless, transparent. *Rock crystal.*

Coloured, and of various degrees of transparency and translucency.

White.

Grey.

Black.

Brown. *Smoky quartz.*

Red. *Compostella quartz.*

Yellow, transparent.

  nearly opaque. *Eisen Kiesel.*

Green, transparent.

  nearly opaque. *Prase.*

Blue, translucent. *Siderite.*

Purple. *Amethyst.*

Primary form a Rhomboid. P,P′=94° 15′. Cleavage parallel to the planes of the hexagonal prism and pyramids of the ordinary crystals. Fracture conchoidal. Hard. 7.0. Sp.gr. 2.69. Transparent to opaque. Lustre vitreous, in some varieties resinous. Colour of almost every variety.

2. *Amorphous.*

Colourless, transparent. *Rock crystal.*

Slightly bluish pale grey. *Milky quartz.*

Slightly greyish with little lustre. *Fat quartz.*

Pale red. *Rose quartz.*

Pale green, a variety of *Amethyst.*

Pale brownish-red, and greenish-grey, slightly coloured, penetrated by Amianthus. *Catseye.*

Blue. *Siderite.*

Containing minute fissures or scales of mica which reflect many brilliant points of light. *Avanturine.*

3. *Massive aggregations of particles in which the crystalline structure is apparent.*

Fibrous, the fibres parallel or divergent.

Granular, the grains varying in size, and cohering with different degrees of force, or being loose in the form of sand.

b. The crystalline structure of the particles not apparent.

Chalcedony. Botryoidal, stalactitic, reniform, nodu-

lar, amorphous, and sometimes in pseudomorphous crystals of the forms of carbonate of lime, (Hornstone,) and of Datholite. (Haytorite.) The nodular varieties are

Onyx, when composed of flat layers or bands of different colours.

Agate, when the bands are concentrically curved.

Other varieties are

Sard, brownish-yellow.

Plasma, dark green, translucent.

Chrysoprase, when pale green.

Carnelian, when white, or brownish or yellowish-red.

Heliotrope, dark green spotted with red, opaque.

Flint, in nodular and tabular masses of various shades of black and grey, and of other colours.

Mixed with variously coloured clays and other extraneous matter, and generally opaque.

Jasper, principally red, yellow, brown, and green of many shades.

Flinty slate. Basanite Touchstone. Colour dark greyish-black.

HYDROUS QUARTZ, No. 155.

Occurs nodular and amorphous.

OPAL distinguished as

Precious, when it presents iridescent colours.

Fire opal, when the internal reflection is bright red.

Hydrophane, when transparency and the colours of the precious opal may be produced by immersion in water. *Appendix*.

Common opal, when the colours, which are very various, are simple.

Semi-opal, when it is dull and opaque.

Wood opal, showing the woody structure.

Cacholong, white opaque opal.

Opal jasper, if mixed with much foreign matter.

Menilite, opaque and brown.

Hyalite, *Fiorite*, in small globular and botryoidal forms.

Geyserite. *Silicious sinter*, No. 159. *Silicious Deposits from the hotsprings in Iceland and elsewhere.*

Structure compact, resembling opal, to fine granular and earthy.

HYDROSILICITE, No. 156.

Appendix to Quartz.

P.M. N.S. 3.71.

Occurs in amorphous masses in serpentine. Fracture even. Soft. Translucent. Dull. Colour white. Feels greasy.

Found at Frankenberg in Silesia, accompanying chrysoprase, opal, and pimelite.

KONILITE, No. 157.

Phil. 207. Leon. 753.

Occurs in the form of a loose white powder in some of the amygdaloids in the Highlands of Scotland and some of the Western Islands. It appears from analysis to be nearly pure silex, but its ready fusibility into a transparent colourless bead induced Dr. Macculloch to suppose that it contained some other matter besides a small portion of lime which easily separated from it.

TRIPOLI, and POLISHING SLATE, No. 158.

Leon. 785.

These appear to be nearly similar compounds of silica in a finely divided state, with small proportions of alumina and oxide of iron.

They are massive, earthy, friable, and of a greyish, brownish, or yellowish colour.

Found in France, Italy, and some parts of Germany.

SILVER.

Stibiuret of Silver.

a. ANTIMONIAL SILVER, No. 26.

Haüy, 3.258. Phil. 236. Haid. 2.427. Leon. 685.

Occurs crystallized, granular, and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ about 120°. Cleavage parallel to the terminal plane and short diagonal of the prism. Fracture uneven. Hard. 3.5. Sp.gr. 9.44, 9.82. Opaque. Lustre metallic. Colour silver-white. Streak the same.

Massive varieties, amorphous, structure granular, foliated.

Found in the Hartz, in Salzburg, and at Guadalcanal in Spain.

Arsenical Stibiuret of Silver frequently accompanies the preceding, of which it is considered a variety containing a mixture of arsenic.

Carbonate of Silver.

a. SELBITE, No. 459.

Haüy, 3.290. Phil. 295. Leon. 702.

Occurs massive and disseminated in veins traversing granite. Structure fine granular. Fracture uneven. Soft. Heavy. Opaque. Lustre metallic. Colour greyish-black.

Found at Altwolfatch in the Black Forest.

Chloride of Silver.

a. LAXMANNITE. *Horn Silver. Muriate of Silver*, No. 67.

Haüy, 3.292. Phil. 295. Haid. 2.154. Leon. 581.

Occurs crystallized and massive.

Primary form a Cube. CRYST. fig. 56. No cleavage. Fracture uneven. Hard. 1.0, 1.5. Sp.gr. 5.55. Translucent. Lustre resinous, bright. Colour grey, yellow, green, blue of different shades, mostly dull. Streak shining. Sectile.

Found with other ores of silver in several parts of Europe and America.

Iodide of Silver.

a. HERRERALITE, No. 57.

Nuevo Systema Mineral, por Del Rio, p. 8.

Structure lamellar. Soft. Externally white, internally yellowish.

Found in serpentine at Albarradon in the State of Zacatecas, Mexico.

Native Silver.

a. SILVER, No. 11.

Haüy, 3.249. Phil. 285. Haid. 2.433. Leon. 699.

Occurs crystallized, dendritic, capillary, and massive.

Primary form a Cube. CRYST. fig. 56. No cleavage. Fracture hackly. Hard. 2.5. 3.0. Sp gr. 10.473. Opaque. Lustre metallic. Colour white. Streak shining.

Massive varieties, amorphous, laminar.

Found in many different places in Europe and America.

b. *Auriferous Native Silver* does not appear to form a distinct chemical species, but differs in the proportions of gold and silver in different specimens.

Seleniuret of Silver and Copper.

a. EUCAIRITE, No. 54.

Mineralogy

Haüy, 3.470. Phil. 294. Haid. 3.94. Leon. 593.
Occurs in small granular masses in a serpentine rock. Soft. Opaque. Lustre metallic. Colour greyish-white.
Found in Sweden.

Sulphuret of Silver.

a. HENKELITE. *Silver Glance*, No. 88.
Haüy, 3.265. Phil. 288. Haid. 3.11. Leon. 635.
Occurs in attached and aggregated crystals and massive.
Primary form a Cube. CRYST. fig. 65. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 7.196. Opaque. Lustre metallic. Colour lead-grey, sometimes blackish from tarnish.
Massive varieties, amorphous, laminar.
Found in most silver mines.

Sulphuret of Silver and Iron?

a. STERNBERGITE, No. 91. *Flexible Sulphuret of Silver of Bournon.* Cat. 209.
E.J S. 7.242. Leon. 779.
Occurs in attached crystals.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 119° 30′. Cleavage distinct parallel to the terminal plane. The laminæ very flexible. Hard. 1.0, 1.5. Sp.gr. 4.215. Opaque. Lustre metallic. Colour dark brown, often with a blue tarnish. Streak black.
Found at Joachimsthal in Bohemia.

Sulphuret of Silver and Antimony.

RED SILVER.

Rhomboidal.

a. BRAARDITE, No. 104.
Haüy, 3.269. Phil. 291. Haid. 3 38. Leon. 610.
Occurs in attached crystals and massive.
Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 108° 30′. Cleavage parallel to the primary planes, generally indistinct. Fracture conchoidal. Hard. 2.0, 2.5. Sp gr. 5.846. Translucent. Opaque. Lustre adamantine. Colour red, of different shades, frequently dark and blackish. Streak red.
Massive varieties, amorphous, structure granular, compact.
Found in many parts of Europe and America.

Oblique Prismatic.

b. MIARGYRITE, No. 105.
Haid. 3.12.
Occurs in attached crystals.
Primary form an Oblique rhombic prism. CRYST. fig. 83. M,M′ = 86° 4′. P,*h*, fig. 91, 101° 6′. Cleavage imperfect. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 5.234. Nearly opaque. Lustre bright metallic. Colour iron-black. Streak dark red.
Found near Freiberg in Saxony.

Right Prismatic.

c. POLYBASITE. *Brittle Silver*, No. 106.
Haüy, 3.280. Phil. 390. Haid. 3.27. Leon. 638.
Occurs in attached and aggregated crystals.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 111° 8′. Haid. Cleavage imperfect. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 6.269. Translucent. Opaque. Lustre metallic. Colour iron-black.
Found in Saxony, Bohemia, and other parts of Europe, and in Mexico and Peru.
Among the numerous specimens named Brittle Silver in the Mineral collections in this Country, we have not observed one agreeing in crystalline form with the above description.

Sulphuret of Silver and Antimony.

a. ROMELITE. *Mine d'Argent grise Antimoniale*, No. 103.
De l'Isle, 3.54. Phil. 290. Haid. 3.30. Leon. 685.
Occurs in attached crystals.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 100°. Phil. Cleavage parallel to the lateral planes. Sp.gr. 5.5. Opaque. Lustre metallic. Colour nearly silver-white.
Found near Freiberg.

Sulphuret of Silver and Copper.

a. SILVERKUPFERGLANE, No. 89.
Phil. 293. Haid. 3.73. Kirwan, 2.121.
Occurs massive. Compact. Fracture flat conchoidal. Soft. Sp.gr. 6.255. Opaque. Lustre metallic. Colour dark lead-grey. Streak shining.
Found in Siberia.

Sulphuret of Silver, Lead, and Bismuth.

a. BISMUTHIC SILVER, No. 90.
Phil. 294. Haid. 3.78. Leon. 618.
Occurs in acicular crystals and massive.
Fracture uneven. Opaque. Colour when first broken light lead-grey, but liable to tarnish.
Massive varieties, amorphous, structure compact.
Found at Shapbach in Baden, in a bed of gneiss.

Sulpho-telluret of Silver and Bismuth.

a. MOLYBDIC SILVER. *Molybdan Silver*, No. 21.
Phil. 287. Haid. 3.127. Leon. 589.
Occurs in small laminated masses at Deutsch Pilsen near Grard, and resembles the Sulpho-telluret of Bismuth, but is said to be composed of sulphur, bismuth, tellurium, and silver. It appears, however, to be an uncertain species.

SODA.

Borate of Soda.

a. BORAX. *Tincal*, No. 424.
Haüy, 2.200. Phil. 192. Haid. 2.52. Leon. 148.
Occurs in single crystals and massive.
Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 101° 30′. M,M′ = 86° 40′. Cleavage parallel to the lateral planes and both diagonals. Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 1.716. Transparent, translucent. Lustre resinous. Colour slightly greyish, greenish, or bluish-white. Streak white.
Found chiefly in a lake in Thibet, and also in Persia and in South America.

Carbonate of Soda.

a. *Oblique Rhombic*, No. 432.
Haüy, 2.207. Phil. 190. Haid. 2.27. Leon. 149.
Occurs crystallized, massive, and in powder.
Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 108° 45′. M,M′ = 76° 12′. Levy. Cleavage parallel to the primary planes and oblique diagonal. Fracture conchoidal. Hard. 1.0, 1.5. Sp.gr. 1.423. Transparent, tranlucent. Lustre vitreous. Colour white, sometimes yellowish or greyish. Streak white. Very efflorescent.
Massive varieties, structure fibrous, granular.
Found abundantly in Hungary and the natron lakes of Egypt, and in some other places.

b. Right Rhombic, No. 433.
Haid. 2.29.
Occurs in crystals lining cavities of the massive varieties of the preceding species.
Primary form a Right rhombic prism. Cryst. fig. 71. M,M′ = 107° 50′. Cleavage indistinct. Fracture conchoidal. Hard. 1.5. Sp.gr. 1.562. Transparent, translucent. Lustre vitreous. Colour white, sometimes yellowish. Streak white. Less efflorescent than the preceding species.

c. Trona, No. 434.
Phil. 190. Haid. 3.164. Leon. 149.
Occurs in crystalline coats, with a fibrous structure.
Primary form an Oblique rhombic prism. Cryst. fig. 83. Measurements uncertain. Cleavage parallel to P, distinct. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 2.112. Transparent, translucent. Lustre vitreous. Colour white, sometimes yellowish. Streak white. Does not effloresce.
Found on the banks of lakes in the Kingdom of Fezzan in Africa.

d. Bicarbonate of Soda? No. 435.
N.J. 35. 48.
Occurs in strata of two to six inches thick on a bed of clay containing muriate of soda. Structure granular. Colour yellowish-grey, does not effloresce.
Found near Buenos Ayres.

Carbonate of Soda and Lime.

a. Gay Lussite, No. 436.
E.J.S. 5.372. P.M. and An. 1.263.
Occurs in imbedded crystals.
Primary form a Right rhombic prism. Cryst. fig. 71. M,M′ = 68° 50′. Cleavage parallel to the lateral planes distinct; less so parallel to the terminal plane. Fracture conchoidal. Hard. 2.5. Sp gr. 1.93, 1.99. Transparent. Lustre vitreous. Colourless.
Found in a thin stratum of soft clay covering a bed of carbonate of soda, called *Urao*, at the bottom of a lake near Lagunilla, a day's journey South-West of Merida in Columbia.

b. Barruelite, No. 437.
P.M. and An. 7.389.
Occurs in crystalline masses. Cleavage distinct, parallel to the planes of a rhomboid, supposed to be similar to that of carbonate of lime. Hard. 3.5. Sp.gr. 2.921. Transparent. Lustre vitreous. Colour not described.
Locality unknown.
Differs from Gay Lussite in the proportions of its constituent elements. But the accuracy of the analysis appears to be questioned by Berzelius.

Chloride of Sodium.

Rock Salt, No. 59.
Haüy, 2.191. Phil. 193. Haid. 2.36. Leon. 584.
Occurs in solution in water, and massive. Structure crystalline, fibrous.
Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 2.0. Sp.gr. 2.257. Transparent, translucent. Lustre vitreous, rather dull. Colour white, grey, red, yellow, blue. Streak white. Taste saline.
Found abundantly in Europe, Asia, Africa, and America. The great salt deposits in this Country are Northwich in Cheshire, and Droitwich in Worcestershire.

Nitrate of Soda.

a. Riverolite, No. 518.
Haüy, 2.214. Phil. 191. Haid. 3.132. Leon. 246.
Occurs with clay in beds of different thickness.
Primary form a Rhomboid. Cryst. fig. 106. P,P′ = 106° 33′. Haid. Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 1.5, 2.0. Sp.gr. 2.096. Transparent. Lustre vitreous. Colour white. Streak white. Taste cool.
Found crystallized in the district of Atacama in Peru.

Sulphate of Soda.

a. Glauber Salt, No. 525.
Haüy, 2.189. Phil. 191. Haid. 2.31. Leon. 125.
Occurs in solution in water, and as an efflorescence on soil and other surfaces.
Primary form an Oblique rhombic prism. Cryst. fig. 83. P,M = 101° 20′. M,M′ = 80° 24′. Cleavage parallel to the terminal planes. Fracture conchoidal. Hard. 1.5, 2.0. Sp gr. 1.48. Transparent, translucent. Lustre vitreous. Colour white. Streak white. Taste cool, bitter.
Found in several places in and out of Europe.

Anhydrous Sulphate of Soda.

a. Thenardite, No. 526.
E.J.S. 6.182. An. n.s. 12.313.
Occurs crystallized.
Primary form a Right rhombic prism. Cryst. fig 71. M,M′ about 125°. Cleavage parallel to the primary planes. Sp.gr. about 2.73. Translucent, opaque. Soluble in water.
Found at Espertines near Madrid.

Sulphate of Soda and Lime.

a. Glauberite. *Brongniartin*, No. 534.
Haüy, 2.215. Phil. 198. Haid. 2.54. Leon. 270.
Occurs in imbedded crystals in rock salt.
Primary form an Oblique rhombic prism. Cryst. fig. 83. P,M = 104° 15′. M,M′ = 83° 20′. Cleavage parallel to P and M. Fracture conchoidal. Hard. 2.5, 3.0. Sp.gr. 2.807. Transparent, translucent, but becomes opaque after immersion in water. Lustre vitreous. Colour yellowish and greyish-white. Streak white. Taste slightly saline.
Found at Ocaña in New Castile, and at Aussee in Upper Austria.

Sulphate of Soda and Magnesia.

a. Reussite, No. 536.
A salt said to consist of about two-thirds sulphate of soda, and one-third sulphate of magnesia, but of which we do not find any published description.

Sodalite, No. 240.
Haüy, 3.59. Phil. 127. Haid. 2.226. Leon. 461.
Occurs in attached and aggregated crystals and massive.
Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the Rhombic dodecahedron. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 2.3. Translucent. Lustre vitreous. Colour greenish-grey and greenish and greyish-white. Streak white.
Massive varieties, amorphous. Structure granular, compact. Minerals from Greenland, Siberia, and Vesuvius have passed under this name, but it is doubtful whether they all belong to the same species.

Somervillite. *Humboldtilite of Manticelli*, No. 374.

Q.J. 16.274. Haid. 3.154. Leon. 484.
Occurs in attached crystals.
Primary form a Square prism. CRYST. fig. 65. P,a = 147° 5′. Cleavage perpendicular to the axis, very distinct. Fracture uneven. Transparent, translucent. Lustre vitreous. Colour dull pale brownish-yellow.
Found in the cavities of matter ejected from Vesuvius.

SORDAWALITE, No. 309.
Phil. 210. Haid. 3.155. Leon. 799.
Occurs massive. Structure compact. Fracture conchoidal. Hard. 5.0. Sp.gr. 2.53. Opaque. Lustre vitreo-metallic. Colour greenish or greyish-black.
Found near Sordawala in Finland.

SPHÆRULITE, No. 248.
Phil. 209. Haid. 3.155. Leon. 780.
Occurs in small spheroidal and botryoidal masses imbedded in pearlsone and pitchstone. Structure fibrous, compact. Hard. 7.0, 7.5. Sp.gr. 2.4, 2.52. Opaque. Dull. Colour grey, brown, red, yellow of various shades.
Found in Hungary, Saxony, Iceland, and Scotland.

SPINELLANE, No. 566.
Haüy, 4.507. Phil. 127. Haid. 3.156. Leon. 459.
Occurs in imbedded dodecahedral crystals in a rock of glassy felspar.
Primary form a Cube. CRYST. fig. 56. Cleavage distinct, parallel to the planes of the Rhombic dodecahedron. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 2.28. Translucent, opaque. Lustre vitreo-resinous. Colour grey, greyish-black, brown.
Found at the Lake of Loach. This might have been called Sodalite with as much propriety as the variety from Vesuvius.

SPINELLE. *Pleonaste. Candite. Balas Ruby*, No. 147.
Haüy, 2.166. Phil. 90. Haid. 2.295. Leon. 544.
Occurs in loose and imbedded octahedral crystals.
Primary form a Cube. CRYST. fig. 56. Cleavage indistinct. Fracture conchoidal. Hard. 8.0. Sp gr. 3.5, 3.7. Transparent, translucent. Lustre vitreous. Colour black, brown, red, yellow, green, blue, violet. Streak white.
Found in loose crystals in Ceylon, and imbedded in carbonate of lime in Sweden and North America.

SPODUMENE. *Triphane*, No. 230.
Haüy, 3.134. Phil. 142. Haid. 2.216. Leon. 433.
Occurs in imbedded crystalline masses of various sizes.
Cleavage parallel to the lateral planes and great diagonal of a Rhombic prism of about 93°. Fracture uneven. Hard. 6.5, 7.0. Sp.gr. 3.17, 3.19. Translucent. Lustre pearly on the cleavage planes. Colour white, sometimes greyish and greenish, and greyish-green. Streak white.
Found in Sweden, the Tyrol, Ireland, and in North America.

Soda Spodumene, No. 231.
Lustre more vitreous than the preceding.

STAUROLITE. *Grenatite. Staurotide*, No. 321.
Haüy, 2.338. Phil. 82. Haid. 2.366. Leon. 409.
Occurs in imbedded crystals.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 129° 20′. Phil. Cleavage parallel to the lateral planes and both diagonals. Fracture uneven. Hard. 7.0, 7.5. Sp.gr. 3.3, 3.72. Transparent, translucent. Lustre vitreo-resinous. Colour dark brownish-red. Streak white.
Found in France, Spain, Portugal, and some other parts of Europe, and in North America.

STILBITE, No. 213.
Haüy, 3.155. Phil. 37. Haid. 2.239. Leon. 193.
Occurs in attached and variously aggregated crystals.
Primary form a Right rhombic prism. M,M′ = 94° 11′. Levy. Cleavage parallel to both the diagonals. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 2.16, 2.5. Transparent, translucent. Lustre vitreous. Colour white, brown, red, yellow. Streak white.
The aggregated crystals are sometimes fasciculated.
Found abundantly in Iceland and the Faroe Islands, and generally in trap rocks.

STRONTIA.

Carbonate of Strontia.

STRONTIANITE, No. 439.
Haüy, 2.43. Phil. 186. Haid. 2.116. Leon. 328.
Occurs in acicular, rarely in tabular crystals, and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 117° 30′. Cleavage distinct parallel to M,M′. Fracture uneven. Hard. 3.5. Sp.gr. 3.6, 3.67. Transparent, translucent. Lustre vitreous. Colour white, grey, pale, brown, and green. Streak white.
Massive varieties, globular, amorphous. Structure fibrous, with a pearly lustre, rarely granular.
Found at Strontian in Scotland, Braunsdorf in Saxony, Leogang in Salzburg, and in Peru.

Barytiferous Carbonate of Strontia.

STROMNITE, No. 440.
Haid. 3.159.
Occurs massive, in veins in clay slate.
Structure fibrous with traces of crystallization. Hard. 3.5. Sp.gr. 3.7. Translucent. Lustre inclining to pearly. Colour yellowish and greyish-white.
Found at Stromness in Orkney.

Sulphate of Strontia.

CELESTINE, No. 530.
Haüy, 2.30. Phil. 187. Haid. 2.126. Leon. 262.
Occurs crystallized and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 104°. Cleavage parallel to the primary planes. Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 3.6, 3.86. Transparent, translucent. Lustre vitreous, pearly on the cleavage surfaces. Colour white, pale blue, and red of different shades.
Massive varieties, nodular, tabular, amorphous. Structure columnar, fibrous, granular.
Found in Sicily, at Bex in Swisserland, at Lake Erie, North America, in the Tyrol, and some other places, and massive near Bristol.

Sulphate of Strontia and Barytes.

GRUNERITE. *Radiated Celestine*, No. 531.
E.P.J. 11.329. Leon. 266.
Occurs in beds in a coarse limestone. Structure radiated. Hard. 3.0, 3.5. Sp.gr. 3.7619. Translucent. Lustre vitreous. Colour white, occasionally with a shade of blue.
Found at Norten near Hanover.

SULPHUR.

a. NATIVE SULPHUR, No. 69.
Haüy, 4.407. Phil. 360. Haid. 3.52. Leon. 595.
Occurs in attached crystals and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 101° 59′. Haid. Cleavage indistinct. Fracture conchoidal. Hard. 1.5, 2.5. Sp.gr. 2.072. Transparent, translucent. Lustre resinous. Colour yellow, greenish-grey. Streak paler.
Massive varieties, stalactitic, of various shapes. Structure compact. Amorphous, structure crystalline, granular, compact.
Found in beds in primitive and secondary rocks in several parts of Europe, and generally in volcanic Countries. Most of the sulphur of commerce comes from Solfatara near Naples.

b. SULPHURIC ACID, No 521.
Phil. 144. Haid. 2.23.
Occurs as a gas issuing from active volcanoes, also in a fluid state in their neighbourhood, and in a concrete form in grottos and caves in the mountain Raccolino, near Sienna, and in some other volcanic districts.
Odour of the gas pungent; taste of the fluid and solid strongly acid and burning.

TACHYLITE, No. 311.
E.N.P.J. 1.364. Leon. 781.
Occurs massive and in plates.
No cleavage. Fracture small, conchoidal. Hard. 6.5. Sp.gr. 2.50, 2.54. Translucent, opaque. Lustre vitreous, vitreo-resinous. Colour brownish and greenish-black. Streak dark grey. Resembles Obsidian.
Found at Süsabühl, near Gottingen.

TALC. *Potstone*, No. 254.
Haüy, 2.489. Phil. 116, 117, 120. Haid. 2.193. Leon. 444.
Occurs in attached and aggregated hexagonal crystals and massive.
Primary form a Rhomboid. CRYST. fig. 106. Cleavage distinct, perpendicular to the axis. Hard. 1.0, 1.5. Sp.gr. 2.713. Translucent. Lustre pearly. Colour white, greyish, and green of many shades. Streak the same.
Massive varieties, granular, earthy.
Found in all parts of the World.
It is probable that several distinct species of Minerals have passed under this name.

TANTALITE. *Columbite*, No. 402 to 408.
Haüy, 4.387. Phil. 269. Haid. 2 390. Leon. 349.
Occurs in attached and imbedded crystals and massive.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 104° nearly. Fracture uneven. Hard. 6.0. Sp.gr. 6.038. Opaque. Lustre imperfect metallic. Colour greyish-black.
Massive variety, nodular, amorphous. Structure granular, compact.
Found in Finland, Sweden, Bavaria, and North America.

TAUTOLITE, No. 375.
E.J.S. 8.181.
Occurs crystallized in the volcanic rocks at Lake Loach.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 109° 48′. Cleavage parallel to M and the greater diagonal. Fracture uneven. Hard. 6.5, 7.0. Sp.gr. 3.865. Opaque. Lustre vitreous. Colour black. Streak grey.

TELLURIUM.

a. NATIVE TELLURIUM, No. 19.
Haüy, 4.379. Phil. 326. Haid. 2.421. Leon. 691.
Occurs in minute attached Hexagonal prisms and massive.
Primary form a Rhomboid. CRYST. fig. 106.
Massive variety, structure granular. Hard. 2.0, 2.5. Sp.gr. 6.115. Opaque. Lustre metallic. Colour tin-white.
Found at Facebay in Transylvania.

b. GRAPHIC TELLURIUM. *Auro-argentiferous Tellurium*, No. 24.
Haüy, 4.380. Phil. 327. Haid. 3.21. Leon. 690.
Occurs in attached flattened crystals.
Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 107° 44′. Phil. Fracture uneven. Hard. 1.5, 2.0. Sp.gr. 5.72. Opaque. Lustre metallic. Colour steel-grey.
Found only in Transylvania.

c. YELLOW TELLURIUM, No. 23.
Phil. 328. Haid. 3.171. Leon. 691.
Occurs in imbedded crystalline laminæ. Lustre metallic. Colour silver or yellowish-white.
Found in Transylvania.

d. BLACK TELLURIUM. *Foliated Tellurium. Auro-plumbiferous Tellurium*, No. 22.
Haüy, 4.381. Phil. 328. Haid. 3.16. Leon. 689.
Occurs in attached and aggregated crystals and in imbedded foliated masses.
Primary form a Square prism. Cleaves into thin flexible laminæ parallel to the terminal plane. Hard. 1.0, 1.5. Sp.gr. 7.085. Opaque. Lustre metallic. Colour dark lead-grey.
Found in Transylvania.

THOMSONITE, No. 212.
Phil. 39. Haid. 3.162. Leon. 208.
Occurs massive. Structure large fibrous, radiated; the fibres prolonged into separate small columnar crystals in the cavities.
Primary form a Right rhombic prism. M,M′ = 90° 40′ nearly. Cleavage parallel to the two diagonals. Fracture uneven. Hard. 5.0. Sp.gr. 2.37. Transparent, translucent. Lustre vitreous. Colour white.

THORITE, No. 376.
Q.J. 6.296.
Occurs massive, and much resembles the Gadolinite of Ytterby. Fracture uneven, very brittle, full of cracks. Hard. about 5.0. Sp.gr. 4.63. Opaque. Lustre resinous, vitreous. Colour black. Streak greyish-red. Powder pale brownish-red.
Found in Syenite, on the Island of Lov-ou, near Brevig, Norway.

TIN.

Oxide of Tin.

a. TINSTONE, No. 139.
Haüy, 4.152. Phil. 250. Haid. 2.384. Leon. 354.
Occurs in attached and imbedded crystals and mas-

Primary form a Square prism. CRYST. fig 65. Cleavage parallel to the lateral planes and both diagonals. Fracture uneven. Hard. 6.0, 7.0. Sp.gr. 6.960, crystallized, 6.319, fibrous. Transparent to opaque. Lustre adamantine. Colour white, grey, black, brown, red, yellow, of various shades. Streak paler.

Massive varieties, reniform, botryoidal, (Wood tin,) structure fibrous; amorphous, structure crystalline, granular.

Found abundantly in Cornwall, Bohemia, Saxony, and in the older rocks in other Countries.

Sulphuret of Tin and Copper.

a. TIN PYRITES, No. 87.

Phil. 254. Haid. 3.163. Leon 624.

Occurs in attached crystals and massive.

Primary form not ascertained. Cleavage imperfect. Fracture uneven. Hard. 4.0. Sp.gr. 4.35. Opaque. Lustre metallic. Colour yellowish-grey. Streak black.

Found in Cornwall.

TITANIUM.

Oxide of Titanium.

a. ANATASE. *Octaedrite*, No. 386.

Haüy, 4.344. Phil. 257. Haid. 2.379. Leon. 358.

Occurs in attached and imbedded octahedral crystals.

Primary form a Square prism. CRYST. fig 65. M,*c* (fig. 68) = 158° 24′. Cleavage parallel to the terminal plane, and to those of the octahedron. Fracture indistinct. Hard. 5.5, 6.0. Sp.gr. 3.826. Transparent, translucent. Lustre adamantine. Colour white, brown, blue. Streak white.

Found in Cornwall, Dauphiny, Brazil, and a few other places.

b. RUTILE, No. 387.

Haüy, 4.333. Phil. 258. Haid. 2 376 Leon. 360.

Occurs in attached and imbedded crystals and crystalline masses.

Primary form a Square prism. CRYST. fig. 65. M,*c* (fig. 68) = 122° 45′. Cleavage parallel to the lateral planes. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 4.249. Transparent to opaque. Lustre adamantine. Colour red and reddish-brown of several shades. Streak pale brown.

Found in Brazil, North America, Spain, and other parts of Europe.

c. BROOKITE? No. 388.

An.P. 1825. Haid. 3.82. Leon. 725.

Occurs in attached crystals.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 100°. Levy. Cleavage parallel to the lateral planes and short diagonal. Fracture uneven. Hard. 5.5, 6.0. Transparent to opaque. Lustre adamantine. Colour deep red and reddish, and yellowish-brown. Streak yellowish-white.

Found at Snowdon in Wales, in large crystals, in Dauphiny, Swisserland, and a few other places.

Silico titaniate of Lime.

a. SPHENE. *Spinthere. Semeline*, No. 394.

Haüy, 4.353. Phil. 262. Haid. 2.373. Leon. 368.

Occurs in attached and imbedded crystals and massive.

Primary form an Oblique rhombic prism. CRYST. fig. 83. P,M = 121° 30′. M,M′ = 133° 30′. Phil. Cleavage indistinct. Fracture uneven. Hard. 5.0, 5.5. Sp gr. 3.468. Transparent to opaque. Lustre adamantine to dull resinous. Colour grey, brown, yellow, green. Streak white.

Found in primitive rocks in several parts of Europe and America.

TOPAZ. *Pycnite. Pyrophysalite*, No. 516.

Haüy, 2.131. Phil. 84. Haid. 2.308. Leon. 401.

Occurs in attached, loose, and imbedded crystals, and massive.

Primary form a Right rhombic prism. M,M′ = 124° 23′. Cleavage parallel to the terminal plane distinct, to the lateral planes indistinct. Fracture uneven. Hard. 8.0. Sp.gr. 3.5. Transparent to nearly opaque. Lustre vitreous. Colour white, yellow of many shades, brownish-yellow, pink, blue, green. Streak white.

Massive variety, (Pycnite,) structure columnar.

Found in Brazil in loose crystals, and in primitive rocks in many other Countries, particularly in Siberia.

TORRELITE, No. 377.

An. N.S. 9.217. Haid. 3.164. Leon. 482. 784.

Occurs in granular masses in the Andover mine, Sussex County, New Jersey. Colour dull vermilion-red. It was at first supposed to contain cerium, but by a later analysis it appears to consist principally of silica, lime, and oxide of iron and manganese.

TOURMALINE. Black, *Electric Schorl*. Blue, *Indicolite*. Red to purple, *Rubellite. Apyrite*, No 429.

Haüy, 3.14. Phil. 139. Haid. 2.349. Leon. 446.

Occurs in attached, imbedded, and aggregated crystals.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 133° 26′. Cleavage imperfect. Fracture uneven. Hard. 7.0, 7.5. Sp.gr. 3.076. Transparent to opaque. Lustre vitreous. Colour white, grey, brown, red, yellow, green, blue.

Found in Siberia, Ceylon, Brazil, North America, and many other places.

TURNERITE, No. 378.

Phil. 382. Haid. 3.166. Leon. 786.

Occurs in attached crystals.

Primary form an Oblique rhombic prism. CRYST. fig. 83. Cleavage parallel to both diagonals of the prism. Hard. 4.5, 5.0. Transparent, translucent. Lustre vitreous. Colour yellow, sometimes brownish.

Found at Mount Sorel in Dauphiny.

The *Pictite* of Lametherie is said by Gallitzin (1802) to be the *Sphene* of Haüy. But it is described as pointed as a graver, and nearly equal to the gems in hardness, and is probably, therefore, *Axinite*.

URANIUM.

Oxide of Uranium.

a. PITCHBLENDE. *Uran-pitch-ore*, No. 138.

Haüy, 4.316. Phil. 267. Haid. 2 393. Leon. 565.

Occurs in reniform and amorphous masses. Structure granular, compact. Fracture uneven. Hard. 5.5. Sp.gr. 6 468. Opaque. Lustre imperfect metallic. Colour greyish and brownish-black.

Found in Cornwall, but chiefly in Saxony and Bohemia.

Phosphate of Uranium.

a. URANITE. *Uran-mica*, No. 504.

Haüy, 4.319. Phil. 267. Haid. 2.182. Leon. 140.
Occurs in attached crystals.
Primary form a Square prism. Cryst. fig. 65. P,c (fig. 68) = 112° 10′. Cleavage parallel to the terminal plane very distinct. Hard. 2.0, 2.5. Sp.gr. 3.1. Transparent, translucent. Lustre adamantine. Colour yellow, greenish-yellow, and green of several shades.
Found in Cornwall, France, and some parts of Germany.
The green variety has received the name of *Chalkolite*, No. 505.

Sulphate of Uranium and Copper.

a. Johannite, No. 563.
E.J.S. n.s. 3.306. Leon. 115.
Occurs in small botryoidal concretions. Hard. 2.0, 2.5. Sp.gr. 3.191. Translucent. Lustre vitreous. Colour bright grass-green. Streak pale green. Soluble in water. Taste astringent, bitter.
Found at Joachimsthal in Bohemia.

Vargasite, No. 379.
A pale greenish Mineral found in Finland, in amorphous masses, having a small columnar structure, and so named after Count Vargas Bodemar.
No analysis or description published.

Werthite, No. 380.
A rolled mass found near St. Petersburg has been so named. Structure small, columnar. Colour pale yellowish-white.

Withamite, No. 381.
E.J.S. 2.218. Haid. 3.170. Leon. 476.
Occurs in small imbedded globular masses, composed of minute crystals, radiating from the centre, and having the form and measurements of Epidote. Hard. 6.0, 6.5 Sp.gr. 3.137. Translucent. Lustre vitreous. Colour red. Streak white.
Found at Glencoe in Scotland.

Wolkonskoit, No. 382.
Occurs massive, amorphous, structure compact. Hard. 2.5. Sp.gr. 2.213. Opaque. Nearly dull. Colour emerald-green. Streak shining. Feels greasy.
Found at Perm in Siberia.

Xanthite, No. 383.
Is said to be yellow Idocrase. Found in North America.

Xantholite, No. 384.
Found in North America. Has the appearance and form of Garnet.

Xylokryptite, No. 589.
Occurs in delicate yellow crystals in Lignite, having a fatty lustre.

Yttria.

Phosphate of Yttria.

a. Tankelite, No. 487.
E.J.S. 327. Leon. 276.
Occurs in aggregated crystals and massive.
Primary form a Square prism. Cleavage parallel to the primary planes. Fracture uneven. Hard. 4.5, 5.0. Sp.gr. 4.56. Opaque. Lustre resinous. Colour yellowish-brown. Streak pale brown.
Found near Lindernoes in Norway.

Silicate of Yttria and Iron.

a. Gadolinite. *Ytterbite*, No. 325, 326.
Haüy, 2.440. Phil. 105. Haid. 2.371. Leon. 526. 500.
Occurs in imbedded crystals and massive.
Primary form an Oblique rhombic prism. Cryst. fig. 83. P,M = 96°. M,M′ = 115°, nearly. No apparent cleavage. Fracture flat conchoidal. Hard. 6.5, 7.0. Sp.gr. 4.238. Slightly translucent. Lustre vitreo-resinous. Colour greenish-black. Streak greenish-grey.
Massive varieties, amorphous, structure compact.
Found at Ytterby, Finbo, and Broddbo in Sweden, and in Greenland.

Tantalate of Yttria, &c.

a. Yttro-tantalite, No. 399 to 401.
Haüy, 4,389. Phil. 271. Haid. 3.173. Leon. 352.
Occurs in imbedded imperfect crystals, and small amorphous masses. Cleavage in one direction. Fracture granular. Hard. 5.0, 5.5. Sp.gr. 5.4, 5.8. Opaque. Lustre vitreo-resinous. Colour black, brownish-black, yellowish-brown.
Found at Ytterby in Sweden.

Tantalate of Yttria and Cerium.

a. Fergusonite, No. 398.
Haid. 3.98. Leon. 738.
Occurs in imbedded crystals in quartz.
Primary form a Square prism. Cryst. fig. 65. Cleavage uncertain. Fracture conchoidal. Hard. 5.5, 6.0. Sp.gr. 5.838. Opaque. Lustre resino-metallic. Colour brownish-black. Streak pale brown.
Found near Cape Farewell in Greenland.

Titaniate of Yttria, Zircon, and Lime.

a. Polymignite, No. 396.
E.J.S. 3.329.
Occurs in imbedded crystals.
Primary form a Right rhombic prism. Cryst. fig. 71. M,M′ = 110° 30′ nearly. Fracture conchoidal. Hard. 6.5. Sp.gr. 4.8. Opaque. Lustre imperfect metallic. Colour black. Streak dark brown.
Found at Frederiksvärn in Norway.

Zeagonite. *Abrazite. Gismondine. Phillipsite*, No. 219.
Phil. 11. Haid. 3.171. Leon. 198.
Occurs in attached crystals, and globular crystalline masses with a fibrous structure.
Primary form unknown, probably a Right rhombic prism, the apparently Square prisms being twin crystals. Fracture conchoidal. Hard. 7.0, 7.5. Transparent to opaque. Lustre vitreous. Colour white, sometimes greyish or reddish. Streak white.
Found at Vesuvius, and frequently in trap rocks. Small crystals of zircon of a pale blue colour have come to this Country ticketed Zeagonite, and have led to an incorrect description of the crystalline form of that Mineral.

Zinc.

Aluminate of Zinc.

Automalite. *Gahnite*, No. 150.
Haüy, 2.170. Phil. 83. Haid. 2.298. Leon. 544.
Occurs in imbedded octahedral crystals, and granular masses.
Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the octahedron, distinct. Fracture conchoidal. Hard. 8.0. Sp.gr. 4.232.

Slightly translucent. Lustre vitreous. Colour dull green. Streak white.

Found at Fahlun and Broddbo in Sweden, imbedded in slaty talc.

Carbonate of Zinc.

CALAMINE, No. 454.

Haüy, 4.181. Phil. 355. Haid. 2.111. Leon. 158.

Occurs crystallized and massive.

Primary form a Rhomboid. CRYST. fig. 106. P,P′ = 107° 40′. Wollaston. Cleavage parallel to the primary planes. Fracture uneven. Hard. 5.0. Sp.gr. 4.44. Translucent, opaque. Lustre vitreous. Colour white, grey, brown, green. Streak white.

Massive varieties, reniform, botryoidal, stalactitic, structure fibrous. Amorphous, structure granular, compact. Both varieties are sometimes found in an earthy state.

Found in England, France, and other places in Europe, and in America.

Red Oxide of Zinc.

a. SPARTALITE, No. 124.

Haüy, 4.179. Phil. 353. Haid. 2.380. Leon. 563.

Occurs in imbedded small nodules and massive. Cleavage parallel to all the planes of a regular hexagonal prism. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 5.43. Translucent. Lustre adamantine. Colour red. Streak orange-yellow.

Massive varieties, amorphous, structure crystalline, granular.

Found in New Jersey, North America.

Biseleniuret of Zinc and Proto sulphuret of Mercury. Del Rio.

a. RIOLITE, No. 55.

Q.J. 4.232. P.M. and An. 4.113.

Occurs massive, structure granular. Sp.gr. 5.56. Lustre metallic. Colour light grey.

Found at Culebras in Mexico.

Biseleniuret of Zinc and Bisulphuret of Mercury. Del Rio.

CULEBRITE, No. 56.

P.M. and An. 4.114.

Occurs massive. Fracture earthy. Sp.gr. 5.66. Dull. Colour dull red.

Found at Culebras in Mexico.

Silicate of Zinc.

a. SMITHSONITE. *Electric Calamine*, No. 168.

Haüy, 4.175. Phil. 254. Haid. 2.108. Leon. 216.

Occurs in attached, and globular, and botryoidal aggregations of crystals.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 102° 35′. Cleavage parallel to the lateral planes. Fracture uneven. Hard. 5.0. Sp gr. 3.38. Transparent, translucent. Lustre vitreous. Colour white, brown, yellow, greenish, and bluish. Streak white.

Found at Matlock in Derbyshire, in other parts of England, and in many other parts of Europe.

Sulphate of Zinc.

a. LISTERITE, No. 539.

Haüy, 4.198. Phil. 356. Haid. 2.46. Leon. 110.

Occurs crystallized and massive.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 91° 7′. Fracture conchoidal. Hard. 2.0, 2.5. Sp gr. 2.036. Transparent, translucent. Lustre vitreous. Colour white, occasionally reddish or bluish. Streak white.

Massive varieties, botryoidal, reniform, stalactitic; structure fibrous. Amorphous, structure granular, compact. Sometimes coating other substances.

Found in most mines that contain the sulphuret, from the decomposition of which this species appears to be produced.

Sulphuret of Zinc.

BLENDE, No. 71.

Haüy, 4.186. Phil. 351. Haid. 3.32. Leon. 622.

Occurs in attached crystals and massive.

Primary form a Cube. CRYST. fig. 56. Cleavage parallel to the planes of the rhombic dodecahedron. Fracture conchoidal. Hard. 3.5, 4.0. Sp.gr. 4.07. Transparent to opaque. Lustre adamantine. Colour white, (New Jersey, North America,) black, brown, red, yellow, green. Streak paler.

Massive varieties, globular, botryoidal, reniform, stalactitic; structure fibrous. Amorphous, structure crystalline, granular, compact. A fibrous variety contains cadmium.

Found in many parts of Europe and America.

Zinc and an Acid not yet ascertained.

a. HOPEITE, No. 571.

Haid. 3.109. Leon. 746.

Occurs in attached crystals.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 101° 24′. Cleavage parallel to the great diagonal, distinct. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 2.76. Transparent, translucent. Lustre vitreous. Colour greyish-white. Streak white.

Found at Altenberg near Aix la Chapelle.

b. TEPHROITE? No. 570.

Leon. 782.

Occurs amorphous. Fracture uneven. Hard. 5.5. Sp.gr. 4.10. Lustre adamantine. Colour ash-grey, becoming black externally.

Found with Franklinite, &c. in New Jersey, North America.

ZIRCONIA.

Silicate of Zirconia.

ZIRCON. *Hyacinth. Jargoon*, No. 180.

Haüy, 2.291. Phil. 99. Haid. 2.368. Leon. 387.

Occurs in attached, imbedded, and loose crystals.

Primary form a Square prism. CRYST. fig. 65. M,c (fig. 68) = 132° 12′. Phil. Cleavage parallel to the lateral planes, indistinct. Fracture conchoidal. Hard. 7.5. Sp.gr. 4.5. Transparent to opaque. Lustre nearly adamantine. Colour grey, brown, red, yellow, pale green. Streak white.

Found in many parts of the World.

Titaniate of Zirconia, Cerium, &c.

ÆSCHYNITE, No. 397.

E.J.S. N.S. 3.28. P.M. and An. 10.188.

Occurs in imbedded columnar crystals in mica and felspar.

Primary form a Right rhombic prism. CRYST. fig. 71. M,M′ = 127°. Cleavage not apparent. Fracture uneven. Hard. 6.0, 7.0. Sp.gr. 5.14. Opaque. Lustre imperfect, metallic. Colour black. Streak greyish-black.

Found at Miask in Siberia.

ZOIZITE, No. 290.

Haid. 2.282. Leon. 476.

Occurs in imbedded and aggregated columnar crystals.

Primary form an Oblique rhombic prism. P,M (unknown.) M,M′ = 116° 30′. Fracture uneven. Translucent. Lustre vitreous. Colour white, grey, brown, green of several shades.

Found in Carinthia, the Tyrol, Siberia, and other places.

ZURLITE, No. 305.

Monticelli, Prodromo de la Mineralogia Vesuviana, p. 392. Leon. 787.

Occurs crystallized and massive.

Primary form a Cube or Square prism. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 2.274. Colour asparagus-green.

Found at Vesuvius.

INDEX.

THE names of those species which are placed in their *alphabetical* order in the preceding *List* are also repeated in this Index for the purpose of giving the entire series of species alphabetically. Those which are chemically arranged in the List will be found here, accompanied by references to the chemical groups in which they stand in the List.

Many synonymes, now nearly obsolete, are omitted in this Index, and it is much to be wished that the Mineralogists of different Countries could agree upon some single nomenclature, which might render a future repetition of any synonymes altogether unnecessary.

A.

B.

C.

M.

N.

O.

P

Q.

R.

S.

X.

Y

Z.

CHAPTER I.

PROGRESS AND PRINCIPLES OF THE SCIENCE.

Geology. Ch. I.

Progress of the Science.

THE term Science, as now universally employed, is understood to express, not only the body of information collected, general laws established, or system recognised in any department of human knowledge, but also the ultimate objects and whole scope of the research. Strictly speaking, perhaps, the former is its legitimate meaning. Thus the Science of Optics or of Acoustics properly signifies the body of methodized information acquired in those branches of human study, but is popularly understood, by way of anticipation, to include indefinitely the expected or possible future accessions of knowledge on the subject.

It is in conformity with this ordinary language that we shall endeavour to give the definition of Geology; for though truly none of the Sciences of observation has made more remarkable progress toward successful generalization than this, yet the prospect of further discovery is so much richer than the retrospect, and the activity and talent employed in the research is so much on the increase, that we can hardly offer too bold and expanded an expression for the ultimate aims of Geology.

It might provoke a smile to recount the singularly contracted notions on this subject which have till lately figured in Works on Geology. The history of the Deluge, the discussion of the character and repositories of minerals, the classification of fossils, the causes and effects of volcanos, belong indeed to this comprehensive subject, but these and many more important inquiries, are only particular branches of the great study of Geology.

One reason of the inadequacy of the definitions usually presented, is probably not confined in its application to any one of the Sciences of observation, *viz.* the difficulty of foreseeing at the commencement of a new study, the direction and extent of its future developement. Mathematical Science, founded upon the pervading idea of relative magnitude, may by this comprehensive definition, anticipate all the various determinations concerning number, and proportion, and direction, which are daily added to its stores, and which are, in fact, the developements of recognised fundamental axioms; but the Natural Sciences have not this advantage, and it is only after they have made great progress, and many detached inferences, drawn from still more scattered data, have been combined into system, that the most able cultivators can clearly discern whereto their labours eventually tend.

Definition. Guided by these views, we shall define Geology as that Science to which it is allotted to investigate the ancient Natural History of the Earth; to determine by observation what phenomena of living beings or inorganic matter were formerly occasioned on or within the Globe, in what order and under what conditions; and from comparative data, furnished by investigation of the present operations of Nature, to infer the general system of successive revolutions which the Earth has undergone before arriving at its present state; and thus, finally, to furnish a complete view of the conditions which have regulated, and of those which do regulate, its system of mechanical, chemical, and vital phenomena.

From the terms of this definition we may at once understand why, in former times, the most able men erred so grievously in their attempts to elucidate the history of our Globe; for, while Geography was imperfectly known, before Commerce and the knowledge of Languages had made us acquainted with the productions and traditions of every clime, before the birth of most branches of Physical Science, it was impossible to accumulate the numerous and exact data from which alone Geology takes its origin. And since the general truths of Geology are made apparent only by the application of the known laws of Modern Nature, it is evident that, before the establishment of those laws, the wisest of the old Philosophers had nothing to substitute for enlightened theory but blind and fanciful conjectures. These are the reasons why the ancient doctrines concerning the World are almost without exception bewildered with the impossible problem of the Creation of Matter, and buried in a chaos of subtle inventions.

Speculative Geology. Cosmogony, not Geology, is the subject of the old traditions of Phœnicia, Chaldæa, Egypt, and China; and the same incurable fault vitiates the learned systems of Epicurus, Aristotle, and Pythagoras.

It is, however, interesting to observe a considerable refinement in the nature of the fictions by which those great men attempted to supply the want of fair deductions. The Epicurean doctrine of atoms, and the primary elements of Aristotle and Pythagoras, are favourably contrasted with the Egyptian egg of the World and the primeval monsters of Chaldæa. Familiarized with Countries in which frequent earthquakes and occasional volcanic eruptions necessarily accustomed the mind to a contemplation of great revolutions in Nature, we find both Aristotle and Pythagoras indulging the ideas of frequent changes in the relative extent of land and sea, and supporting this doctrine by reference to historical facts concerning subsidence and elevation of land, to the occurrence of marine shells far from the sea, and to the ordinary processes of Nature. But, in this respect, the Geographer Strabo appears to have far outstripped all his predecessors; for he distinctly alludes to the various explanations of the phenomena of marine remains, proposed by Eratosthenes, Xanthus, and Strato, and adds his own view of the matter, in terms not very different from those employed at the present day by the advocates of the gradual elevation of our solid land from the bed of the sea, as may be known by consulting the excellent review of Geological opinions given by Mr. Lyell.

The ten centuries of war and commotion which suc-

ceeded the destruction of the Western Empire, were less favourable to the growth of Physical Science than even those which had preceded; and while all the learning of the world was shut up in cloisters, and confined to one class of Society, we cannot wonder that the grand cosmogonies of the Ancients should have dwindled into puerile discussions. Learning was in chains, but it was nevertheless spread abroad through Christendom, and waited but for the extension of Geography and Commerce, by the maritime discovery of India and America, to be emancipated from its thraldom, and for the discovery of the Art of Printing to be excited to energy and enthusiasm, by the Physical and Astronomical discoveries of Kepler and Galileo.

It was not, indeed, till the Inductive Philosophy, budding in Galileo, blossoming in Bacon, and rich with fruit in Newton, had been widely disseminated among mankind, that we were entitled to look for fixed data and limited generalizations in any branch of Natural Science. The diffusion of this mode of philosophizing may be said to have withdrawn the veil of prejudice which had previously obscured the visible Creation, and to have really generated the Sciences which treat of the properties of Matter and the phenomena of Life.

Three different classes of phenomena have conducted men of observation to a partial acquaintance with the stratification of the crust of the Earth.

Origin of Inductive Geology.

1. The arrangement of the various soils in England.
2. The appearances in the mines of Germany.
3. The remains of plants and animals entombed in the strata of England, France, and Italy.

Agriculture.

The early advancement of Agriculture in a Country so populous, and of so diversified an aspect as England, necessarily produced a very intimate knowledge of different soils; and as these depend on the nature of the substances beneath, which range in regular courses, it is not surprising that maps of the soil should have been early proposed by agriculturists. Dr. Lister, residing in Yorkshire, where the ranges of soil are very well defined, was the first to propose to the Royal Society, in 1683, a Map of the soils of England.

"We shall be better able," he says, "to judge of the formation of the Earth, when we have duly examined it, as far as human art can possibly reach, beginning from the outside downwards. And for this purpose, it were advisable that a Soil or Mineral Map, as I may call it, were devised. The soil might either be coloured by a variety of lines or etchings: but great care must be taken very exactly to note on the Map where such and such soils are bounded. As for example, in Yorkshire, the *woods*, (wolds,) chalk, flint, and pyrites, &c. 2. *Blackmoor*, moors, sandstone, &c. 3. *Holderness*, boggy turf, clay, sand, &c. 4. *Western mountains*, moors, sandstone, coal, ironstone, clay, sand, &c. *Nottinghamshire*, mostly gravel, pebble, clay, sandstone, hall-plaster, or gypsum, &c. Now if it were noted how far these extended, and the limits of each soil appeared on a Map, something more might be comprehended from the whole and from every part, than I can possibly foresee, which would make such a labour very well worth the pains. For I am of opinion such upper soils, if natural, infallibly produce such under minerals, and for the most part in such order. But I leave this to the industry of future times."

This scheme was partly executed by the County Reports presented to the Board of Agriculture, the earliest of which dates from 1794; but the investigation being usually unconnected with sound views of the interior conformation of the Earth, few of these detached efforts led to any important results. Packe, in his *Chorographical Chart of East Kent*, (1743,) has shown what admirable general views of the Physical Geography and leading rocks of a district may be entertained, without that combination of results which leads to Geology.

Mining.

Miners in every period must have been acquainted with the order of succession of the rocks through which they seek the treasures of coal and metal; and in a tract consisting of alternating coal-seams, limestones, sandstones, and shales, as at Aldstone Moor, in Cumberland, the range and extent of the different strata must always have been familiar to the workmen.

There must therefore always have been a MINERALOGICAL SCHOOL OF GEOLOGY in every Country in which rich subterranean treasures attracted the attention of mankind.

Agricola embodied the floating information of the miners of Saxony, as early as 1546; (*De Naturâ Fossilium*;) and the appearance of five complete systems of Mineralogy in Sweden, and three in Germany, between 1730 and 1762, sufficiently proves the very general interest in the subject which prevailed in these great mining districts.

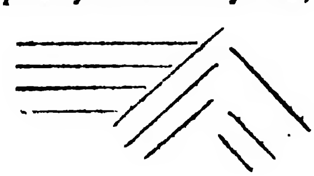
Those Works are principally devoted to a description of the most prominent Minerals, and it is only incidentally that we gain from them proofs of the considerable, though detached information which the authors really possessed concerning the manner in which minerals constitute, by their assemblage, the crust of the Earth.

In 1750, however, Tylas, a Swede, and in 1756, Lehmann, a German, broke through the fetters of a mere mineralogical method, and by proving a regular order of superposition among stratified rocks, opened the way to the sagacious generalizations of Werner and the cautious inductions of Saussure.

Werner

A peculiar set of opinions concerning the formation of the Earth, has been honoured by the title of the Wernerian Theory; and the pupils of Werner who had found proof of the truth of his practical inferences, may be readily pardoned for the determination which they have shown to uphold the hypothetical notions of their master. But if we wish to ascertain the real value of the benefits which the researches of Werner have conferred upon Geology, we must forget his Theory, and view only the data which he collected for its foundation.

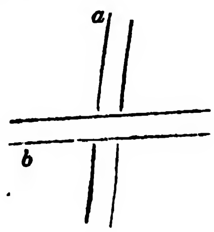
Werner was educated amidst the mines, and in the society of the most eminent Mineralogists of Saxony; their experience and their opinions became his own, and doubtless swayed and directed the energies of his mind. To judge from his own Works, and from the course which his pupils have so long pursued, the principal point of view under which Werner contemplated the rocks and metallic veins of Germany, was the relative period of their production. Lehmann had, indeed, taken the same course, and already distinguished primary and secondary rocks,



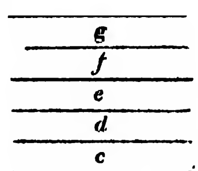
the former existing in mountain chains, mostly stratified at high angles of declination, and devoid of organic remains, the latter disposed more horizontally, and stored with the reliquiæ of life. But Werner, with characteristic tact and boldness, applied this method of investigation to every case, and took it as the grand basis of his classification of rocks.

Basis of his system.

"When two veins (a b) cross, and one of them (b) cuts through the other, (a,) the one which is divided (a) is the more ancient."



Among stratified rocks superimposed on one another, the lower members of the series, those which lie nearest the centre of the Earth, were deposited first, and the relative antiquity of the different strata is exactly in the order of their position. Thus c is the oldest rock of the series, c, d, e, f, g.



By this manner of proceeding in the instance of the Hartz Mountains, Werner was enabled to frame a system or classification of rocks in the order of their respective position as far as could then be ascertained, and consequently in the order of their consecutive formation. Thus the Brocken Mountain was described by Werner and his followers as a central cone of granite, upon which on all sides round were laid various other rocks in a certain and constant order of succession; as granite, clay-slate, limestone, greywacke and greywacke-slate, old red sandstone, limestones, gypsums, sandstones and limestones; the upper and newer strata having their outgoing or terminal edges lower and lower continually.

Werner presumed that this order of succession among these rocks would be found to prevail in all parts of the World, and thus announced a grand principle in the construction of the Earth which was destined to have a most beneficial effect on Geological theory and observation. For, on the one hand, it dissipated the chaotic dreams of those who maintained that the whole crust of the Earth was to be viewed as a mass of sediment from the waters of "the Deluge;" and on the other, exhibited the most important subject of inquiry respecting the constitution of the Earth, and fixed a precise method of investigating it.

Extending his views through other parts of Germany, Werner completed the following system of successive formations. (*Jameson.*)

Werner's series of formations.

The lowest and oldest series of rocks discoverable by examination is supposed to be of crystalline origin, to be devoid of organic remains, and to have been originally, as at present, stratified at high angles of inclination. These are called by Werner

Primitive Rocks.

Such are:

Granite,	Porphyry,
Gneiss,	Sienite,
Micaceous schistus,	Topaz rock,
Argillaceous schistus,	Quartz rock,
Primitive limestone,	Primitive flinty slaté,
Primitive trap,	Primitive gypsum,
Serpentine,	Eurite, or whitestone.

A second series of rocks appearing to be partly of crystalline and partly of mechanical origin, containing some remains of plants and animals, with slopes of stratification less remarkable than the former, is named by Werner, on account of these intermediate characters,

Transition Rocks.

Transition limestone,	Greywacke,
Transition trap,	Transition flinty slate.

The third series consists of strata more decidedly of mechanical aggregation with abundance of organic exuviæ, and from the greater frequency of these strata in the flatter regions of the Globe, where their planes of stratification are nearly level, they are called

Flœtz (flat-lying) Rocks.

1st or old red sandstone.
1st flœtz limestone.
1st flœtz gypsum.
2d variegated sandstone.
2d flœtz gypsum.
2d flœtz limestone, or muschelkalkstein.
3d sandstone, or quadersandstein.
3d limestone, or planerkalkstein.
Flœtz trap.
Independent coal formation.
Newest flœtz trap.

Lastly, various sandy and argillaceous strata, imperfectly known to Werner, but since ascertained to contain the whole vast series of tertiary strata, are included by him under the title of Alluvial Deposits.

That this classification is partly erroneous in principle, and in all respects incomplete and inadequate to the rigour of modern investigation, is apparent at a first glance, but it obviously contains the essence of all subsequent arrangements, *viz.* a determined reference to the antiquity of the deposit. Werner is, therefore, entitled to the distinguished praise of having established one of the most important general laws yet ascertained respecting the structure of the Earth. He has proved that its stratified rocks are laid one on another in a certain order of succession, which is the same, or very similar, over large parts of the Earth's surface. No one before Werner was able to perceive in any Country a regular system or series of strata, much less to imagine such a series to be universal.

Mitchell.

It has been usual, especially in England, to quote a variety of persons before the date of Werner, to whom the honour of first declaring the principles developed by the Professor of Freyberg might with more justice be ascribed. The nature of his obligations to his own Countrymen has been already sufficiently stated. Mitchell, one of the most talented of the Natural Philosophers of England during the middle of the XVIIIth Century, who, for a short time, filled the Woodwardian Chair of Geology at Cambridge, and afterwards resided in Yorkshire, had certainly made himself acquainted with the series of English strata, especially in the Northern

Counties, and had even gone so far as to discover some of the most important general relations between the Geological structure and the Physical features of the Globe, defining with a masterly hand the mutual dependence of mountain ranges and lines of stratified rocks.

Whitehurst.

The merit of Whitehurst, also, both as a theorist and as an observer, is very considerable. He states the object of his Work, published in 1792, to be "to trace appearances in Nature from causes truly existent; and to inquire after those laws by which the Creator chose to form the World; not those by which he might have formed it, had he so pleased." His mode of proceeding is exactly in conformity with the first clause of this sentence; for his whole Work is a finely woven web of plausible deduction and conjecture, founded on general Physical considerations, and *supported* or *illustrated* by a selection of corresponding facts and observations. This inverse process is certainly, in many respects, characteristic of a Cabinet Geologist; and yet this volume contains abundant proof, that its author was both well acquainted with a great variety of important data in Geology, and possessed of sufficient generalizations to develope their value. What is stated by Whitehurst concerning the succession of strata in Derbyshire and other parts, was chiefly derived from the miners and colliers, who, certainly, for a hundred years before the dawn of sound Geology, knew perfectly the almost invariable sequence of strata in their own districts.

Saussure.

The value of Saussure's distinguished services to clear the way for legitimate inductions in Geology cannot be better expressed than in the following passage of Cuvier, wherein he is compared with Werner.

En effet, la partie purement minérale du grand problême de la théorie de la Terre a été étudiée avec un soin admirable par De Saussure, et portée depuis à un développement étonnant par Werner et par les nombreux et savans élèves qu'il a formés.

Le premier de ces hommes célèbres, parcourant péniblement pendant vingt années les cantons les plus inaccessibles, attaquant en quelque sorte les Alpes par toutes leur faces, par tous leurs défilés, nous a dévoilé tout le désordre des terrains primitifs, et a tracé plus nettement la limite qui les distingue des terrains secondaires. Le second, profitant des nombreuses excavations faites dans le pays qui possède les plus anciennes mines, a fixé les lois de succession des couches; il a montré leur ancienneté respective, et poursuivi chacune d'elles dans toutes ses métamorphoses. C'est de lui, et de lui seulement, que datera la Géologie positive, en ce qui concerne la naturale minérale des couches: mais ni Werner ni De Saussure n'ont donné à la détermination des espèces organiques fossiles dans chaque genre de couche, la rigueur devenue nécessaire, depuis que les animaux connus s'élèvent à un nombre si prodigieux.

Inductive Geology principally founded on the organic reliquiæ.

The grand fact upon which, in all Ages, Geological inquiries have hinged, the occurrence of marine animals far from the sea and deep in the solid bosom of the Earth, was so far understood by the Ancients, that they had ascertained the general agreements of fossil and recent marine shells, nor does there appear the least trace of doubt on this subject in their writings. But warm discussions arose concerning them among the Naturalists of Italy, and at a later period, those of France, England, and Germany, Countries in which those exuviæ are particularly plentiful and various.

The XVIth Century was wholly wasted in the ridiculous dispute whether the fossil shells were genuine marine exuviæ, or mere *lusus naturæ* produced by a plastic power or fermenting fatty earth? and the question assumed a more difficult character from the addition of another, whether, if they were genuine petrifactions, they were all deposited by the Noachian Deluge? In examining both of these points the Italian Philosophers were by far the most conspicuous, and it is difficult to understand how the sound conclusions of Steno and Scilla could fail to become the universal creed of Geology; yet long after Palissy in France had produced unanswerable evidence that fossil shells were the genuine exuviæ of ancient marine animals, men voluntarily shut their prejudiced eyes to this most simple of all truths. The XVIth Century closed before the expiration of this absurd controversy; but as Truth infallibly gains strength by even the most unworthy contests, the strong interest attached to the solution of this problem spread universally among Naturalists the conviction that great discoveries concerning the structure of the Earth were to be accomplished, and the mode of contemplating its connection with Zoology received very capital improvements.

Progress of Fossilogy in England.

In England, especially, the superior interest which belonged to the thousands of fossil plants and animals, was fully understood by Llwyd, Ray, Lister, Woodward, and Moreton; who by their rich collections, and splendid publications, and resolute though unsuccessful efforts to deduce the causes which had thus buried and preserved imperishable in their everlasting tombs the organic remains of a former World, undoubtedly kindled that ardent spirit of inquiry respecting the structure of the Earth, for which the English Philosophers of the XVIIth Century were so honourably distinguished.

Nevertheless, the progress of Geology in England was still retarded by the fettered condition of other Sciences, and by a peculiarly unhappy conjunction of Truth and Fiction. The correct view of the original nature of "formed stones, or petrifactions," was coupled by Woodward and his numerous followers with the assertion, that all the strata superimposed on one another in the crust of the Earth, with all their included myriads of fossil animals and plants, were deposited by one general flood, "the Deluge!" This fatal error, the stumbling-block of the Geologists of the XVIIth Century, lay at the root of the brilliant hypotheses of Burnet, Woodward, and Whiston; and now, though discarded by every sound Geologist, it remains a serious impediment to the diffusion of correct general principles. One great merit, however, strikingly characterises the early English School of Geology, even in its greatest aberrations, a thorough conviction that the organic remains entombed in the Earth were the surest evidence of the revolutions which it had undergone.

Lister.

In consequence, the whole island was filled with collections of fossils, which were compared with native and exotic living species, and almost every Naturalist of note from the time of Lister contributed something to the stock of information respecting them. That distinguished man, equally industrious and fortunate, and in general free from theoretical prejudice, had the glory of perceiving and of recording in a single instance the principle of mutual dependence between the strata and their organic remains, which afterwards, generalized and promulgated by Smith, became the most important instrument of investigation which has ever been presented to Geology.

Speaking of a small species of belemnites, (*B. Lis-*

teri,) which is figured in his *Historia Animalium Angliæ*, he says it is found in all the cliffs *as you ascend the wolds*, for above a hundred miles in compass, at Speeton, Londesbro' and Caistor, but always in a *red, ferruginous earth*. This correct and remarkable result is a striking example of the possibility of even holding in the hands a brilliant discovery, without knowing its value, or taking any steps to ascertain its importance.

Smith.

A century later, the perception of the same truth, in *several instances* near Bath, and the demonstration of its applicability to the whole secondary series of the strata of England, enabled Mr. Smith, by his own unaided efforts, to establish the Geology of England on a basis from which it can never be shaken; an accurate classification of the stratified rocks, in the order of their relative antiquity, accompanied by Catalogues of their organic contents, and a Map of their ranges on the surface of the Island in conformity with the section of the interior.

The following Table, taken almost verbatim from Dr. Fitton's valuable notes on the History of English Geology, (*Phil. Mag.* 1832,) presents the list of English strata as published by Mr. Smith in 1815, and the corresponding arrangement at present admitted among Geologists; and thus at one view may be seen the entire distinctness of Mr. Smith's whole system of classification and method of naming, from that of any earlier continental writer, and the almost perfect exactness with which his views and names have been adopted by the modern School of English and European Geology.

Smith, 1815. Characters of natural Districts formed by Groups of Strata.	No.	Names of Strata on Mr. Smith's Map and Sections.	1833.		Present Names.
		(*These beds above the chalk not noticed by Smith.*)	Strata above the chalk		Crag of Suffolk. Marine and freshwater strata of the Isle of Wight and Dorsetshire.
Plains	1	London clay			London clay.
	2	Clay or brick earth			Plastic clay.
	3	Crag (*this should have been placed first*)			Sands above the chalk.
	4	Sand and light loam			
Chalk hills	5	Chalk {Upper, with flints; Lower, without flints}	Cretaceous strata		Chalk {Upper. Lower.
	6	Green sand			Upper green sand.
Clay vales	7	Blue marl			Gault.
	8	Iron sand			Lower green sand.
		(*The Wealden group not distinguished by Smith.*)		Wealden	Weald clay. Hastings sands. Purbeck limestone.
	9	Portland rock	Oolite strata	Upper oolite.	Portland oolite.
	10	Sand			Sand.
	11	Oaktree, or North-Wilts clay			Kimmeridge clay.
				Middle oolite.	Upper calcareous grit.
	12	Coral rag and pisolite			Coralline, or Oxford oolite.
	13	Sand and sandstone, or calcareous grit			Lower calcareous grit.
	14	Dark blue, or Clunch clay			Oxford clay.
	15	Kelloway stone			Kelloway stone.
Stonebrash hills	16	Cornbrash		Lower oolite.	Cornbrash.
	17	Hinton sand and sandstone			Sand and sandstone.
	18	Forest marble			Forest marble.
	19	Clay			Bradford clay.
	20	Great oolite			Great oolite.
	21	Fullers' earth and rock			Fullers' earth and rock.
	22	Under oolite			Inferior oolite.
	23	Sand			Sand and grit.
	24	Marlstone		Lias	Upper lias clay.
Marl vales	25	Blue marl			Marlstone.
					Lower lias clay.
	26	Blue lias			Blue lias.
	27	White lias			White lias.
	28	Red marl and gypsum	Saliferous strata		Red marl and gypsum.
					Red sandstone.
	29	Magnesian limestone			Magnesian limestone. (Zechstein, &c.)
Coal tract		Soft sandstone			Rothetodtelliegende.
	30	Coal districts	Carboniferous strata		Coal measures.
Mountainous	31	Mountain limestone			Mountain or carboniferous limestone.
	32	Red and dun stone			Old red sandstone.
	33	Various, killas or slate			Slates, &c.
	34	Granite, sienite, and gneiss			Granite, &c.

To study the monuments of Nature according to the principles developed by Mr. Smith; to ascertain by the order of succession and by the organic remains what were the contemporaneous effects of the natural agents employed in the formation of the Earth in all parts of the World; is the great problem of modern Geology. By the aid of Zoological and Botanical researches we determine the *relative* antiquity of every species of fossil plant and animal, and assign the *relative* period during which its existence was continued. Orthoceratites productæ, trilobites, and many crinoides, belong to the older and lower rocks; certain species of echini and shells mark the oolitic strata; while others belong to the chalk; and a series of plants, corals, shells, and vertebral remains, lies above the chalk, but is not found below. Such inferences, drawn from observations in Europe, have been found constant even in the New World; and if the powerful instrument of research thus placed in the hands of the observer, be wielded with the caution requisite in questions of analogy, the time is probably at hand when the principles disclosed by Mr. Smith's researches near Bath, and illustrated by Cuvier's philo-

sophical description of the environs of Paris, will be found universally applicable; and the distant slopes of the Himalayah and the Andes, and the shores of Australia and Greenland, will be united in the mind of the Geologist who contemplates their coeval stratification.

Hypotheses.

We shall here close our short account of the growth of Geology into a Science, without being tempted to indulge in the vain amusement of ridiculing those crude and visionary schemes which have too long been known by the misapplied title of Theories of the Earth. While the paths of observation, along which alone the foundations of the Science are to be sought, were hard and difficult, those of hypothesis were easy, flowery, and inviting. The globular figure of our Planet, the inequality of its surface, and the occurrence of marine shells in mountains far from the sea, have been thought sufficient data for rashness and speculation to construct detailed Theories of the Earth, to determine the constitution of its centre, and to describe, as if they had actually beheld them, the successive revolutions which it had undergone.

These unfortunate hypotheses were most numerous and discordant during the period when positive Geology had made the least progress; with the advancement of knowledge they diminished in number and improved in consistency, and at the present moment, though every professed Theory has lost its power of fettering the mind, there is a tacit but almost universal agreement in these fundamental principles of structure, and circumstances of origin, by which not only every passing Theory must be judged, but to which also all good observations and sound inductions must be referred. To develope these principles in a settled order, to illustrate by their aid the Geological structure of the British Isles, and to connect the Geology of Britain with that of Europe and the terraqueous Globe at large, and thus to rise by a legitimate process to the most comprehensive inferences which the subject admits of, is the aim of the following pages.

We shall not, at the outset of our inquiry, prejudge the important questions which will arise for discussion, by deciding between Huttonian and Wernerian, or any other hypotheses; but allowing to their ingenious authors the merit of having really promoted Geology by stimulating curiosity and by directing inquiry, we shall for the present neglect them altogether, except so far as they may assist us to read well and interpret aright the rich and impartial volume of Nature.

Modern cultivators of English Geology.

But though Geology will not again own a master, its cultivators can never cease to be grateful to their ancient leaders; and many names connected with the general progress of English Geology in recent times, here demand the warmest expression of gratitude. The English system of Geology, based on the extensive labours of Smith, has been fully illustrated in Greenough's *Geological Map*, Buckland's *Reliquiæ Diluvianæ*, and Conybeare's *Geology of England and Wales*, a Work certainly not yet surpassed in merit, nor soon to be excelled unless by the continuation of it, which is anxiously expected, from the combined labours of Conybeare and Sedgwick. Scotland has been surveyed by Jameson and Mc Culloch, amply described by Boué, and put in relation with English Geology by the eminent researches on secondary rocks of Sedgwick and Murchison. Nearly the whole of Ireland has been ably treated by Weaver. The mineral condition of the British Islands has been to a great extent developed by Sowerby, and the history of British fossil plants is in the hands of Lindley and Hutton. If from these comprehensive Works we should pass to those more local and definite discoveries which are the ultimate strongholds of the Science, many pages would not suffice to hold the praise so justly ascribed to De la Beche, Farey, Horner, Lonsdale, Lyell, Mantell, Miller, Webster, and other eminent names which will appear in the following descriptions. To the Geological Society of London, established in 1807, as a Body, belongs the high and enviable praise of unwearied and exciting activity, sound preference of permanent facts to transient Theories, invincible liberality of sentiment, and prophetic anticipation of that glorious expansion of the Science, which now claims for it the countenance and the active cooperation of every person interested in the interpretation of Nature, or concerned in the increase of the national wealth. Finally, there is yet a tribute to be offered to one whose ear is now dead to grateful praise, the man whose genius restored the vanished forms of Nature, and united the Zoology of all Ages of the World. What monument can be required for Cuvier, so long as the wonderful works of Creation claim the admiration of mankind?

Materials in the Earth.

Mean density of the Earth.

The first question which presents itself to the inquirer into the Natural History of the Earth is, what are the materials employed in its construction? To answer this question fully, and in all its extent, is now, and will, probably, for ever remain impossible, because with respect to the interior of the Globe we can learn nothing from direct observation, nor infer from Astronomical researches any thing more than that the materials, whatever they are which compose the more central parts, must have *there* a Specific Gravity, very much greater than that of the rocks which appear near the surface. The mean density of all the predominating rocks hitherto discovered is about twice and a half that of water; but the mean density of the whole terraqueous mass is four and a half times, or perhaps five times that of water. We may, therefore, safely conclude that the central portions are much heavier than the external crust; but beyond this all is speculation.

Specific Gravity of the materials.

It must not be concluded that because in the central parts the materials, whatever they are, have a Specific Gravity greater than those near the surface, they would also remain heavier if brought to the surface, for the compressibility of Matter under pressure would necessarily tend to the condensation of the internal nucleus of the Earth, and that in so high a degree, if the internal substances be of the same compressibility as those in the crust of the Earth, as to make the mean density of our Planet very much higher than it is known to be. Putting out of view the question of the Chemical relations of the internal substances of the Globe, and confining ourselves to Mechanical considerations alone, we should have, as conclusions of the greatest probability which the subject admits of:—

First, that the superior density of the internal parts of the Globe is occasioned by the accumulated pressure which they have to sustain.

Secondly, that the effects of this pressure in condensing the internal parts of the Globe would be far more considerable than they are, were they not resisted within by some general antagonist force; such as the

expansive power of heat, or an extraordinary want of compressibility among the particular substances operated on.

Thirdly, That the Earth's spheroidal figure has been attained in consequence of its having formerly been entirely fluid, during rotation on its axis, and is preserved because the internal arrangement of its materials, whether solid or fluid, is in equilibrio with the velocity of its rotatory movement.

Limitation of inquiry.

It cannot be too often nor too early impressed upon the mind of the student that Geology has no connexion with systems of Cosmogony. It is wholly a Science of observation and inferences, and limited to the phenomena presented within a small depth from the surface of the Earth. The regular disposition of the materials of our Planet does indeed permit us, in many cases, to infer, with the highest probability, what is the condition of its interior to a depth far beyond that actually visible to human eye; but still all the aids of Inductive Science are ineffectual to penetrate more than a few miles below the soil. It may, indeed, be the case, since the level from which volcanos arise is uncertain, that the materials which they vomit have been derived from greater depths, but the great improbability that these materials, after undergoing fusion, should be restored to their original condition, must make us hesitate to adopt volcanic products as evidence of the exact nature of the substances in the interior of the Earth. Our observations are, therefore, nearly confined to what is technically called the Crust of the Earth, and our legitimate inferences descend no lower than the rocks which appear in this crust.

Earthy compounds

There is hardly any tract of country so limited as not to show a considerable diversity of earthy aggregates. Even in those districts which possess neither quarries, nor mines, nor cliffs, nor natural valleys, the surface of the land and the shores of the sea are generally strewed with fragments of different stones transported by some ancient powerful currents from regions in which Nature is more prolific, or more clearly reveals her treasures.

In the more level Countries the principal varieties of the earthy compounds or aggregates are included in the terms limestone, sandstone, and clay, of different colours, hardness, and fineness of grain. Each of these great divisions of rocks contains essentially a peculiar species of earth which imparts to the mass a particular derivative character. Thus,

Lime is the base of limestone,
Silica of sandstone,
Alumine of clays.
Magnesia is an essential ingredient in certain *limestones*.
Carbon is the characteristic element of coal,
Soda of salt.

If we now turn our attention to the mountainous tracts, where crystallized minerals present themselves in an endless variety of combination; we shall, perhaps, be led to expect a corresponding abundance of primitive substances. But Chemistry has taught us that all this seeming inexhaustible variety is occasioned by a few earths, metals, and combustibles, and some of these are so rare, and even solitary in their occurrence, as to be of little importance in this inquiry. By far the greater number of earthy minerals are composed of the same four substances, as limestones, sandstones, and clays, variously combined with alkalies and acids, and differently coloured by metallic oxides, &c. A good general knowledge of silicious, aluminous, calcareous, and magnesian minerals and rocks, is therefore the portion of Mineralogy most essential to a Geologist.

Elementary substances.

All the various aerial, liquid, and solid compounds which belong to this Globe are reducible to about fifty-four ingredients, which are termed simple or primitive, because, in the present state of Chemical Science, they appear incapable of further decomposition. Of these

Forty-three are *metallic bodies*, brilliant, electropositive, and, with the exception of potassium and sodium, heavier than water.

Of these thirteen produce, by union with oxygen, the Earth and alkalies,—

Aluminum, Silicium, Yttrium,
Glucinium, Thorinium, Calcium,
Magnesium, Zirconium, Strontium,
Barium, Lithium, Sodium, Potassium.

Five decompose water at a red heat,—

Manganese, Zinc, Iron, Tin, Cadmium.

Twenty-four do not decompose water at any heat. The more oxidable are,

Arsenic, Antimony, Copper,
Molybdena, Uranium, Tellurium,
Chrome, Cerium, Nickel,
Vanadium, Cobalt, Lead,
Tungsten, Titanium, Mercury,
Columbium, Bismuth, Osmium.

The less oxidable,—

Silver, Rhodium, Gold,
Palladium, Platinum, Iridium.

Eight non-metallic combustibles,—

Sulphur, Iodine, Carbon,
Phosphorus, Bromines, Fluorine?
Silenium, Boron.

Four gases,—

Hydrogen, Oxygen, Azote, Chlorine.

Every substance in this list is found in the mineral kingdom; and while the Chemist examines them separately in his closet, the Mineralogist studies their combinations in the field.

Minerals.

It may, perhaps, be imagined that innumerable combinations are derived from these fifty-four primary ingredients. But as many of them are excessively rare, as the remainder combine only upon certain principles, the number of mineral species really determined is, in fact, very small, perhaps hardly exceeding 300. Nor is the Geologist always called upon to make himself acquainted with all even of this moderate number. Unless his labours are devoted to the detailed phenomena of volcanic productions, or of mineral veins, he will seldom have occasion to observe more than one-tenth of the number. The reason of this is that a large portion consists of rare and local species, and that in combining to form rocks, the others are associated in families, and united into specific compounds without much permutation. Thus quartz, felspar, hornblende, chlorite, and mica, frequently occur together in granitic rocks, but other minerals, as calcareous spar, &c. scarcely ever accompany them. In consequence, then, of the rarity of many minerals, and the uniformity of the assemblage of others, there is really much less difficulty than might be expected in recognising and discriminating the rocks. To class and to describe them is difficult, to compare and to know them is easy.

Supposing, then, that the student has already made himself acquainted with the more common and remarkable rocks, as limestone, sandstone, and clay, various kinds of slates, basaltic, porphyritic, and granitic rocks,

we shall now proceed to inquire in what manner they are arranged in the Earth.

Stratification.

The best way of prosecuting this inquiry, is to begin at home, where precise information can be most easily acquired; next to compare our own with neighbouring districts; and, finally, extending our views over the whole surface of the Globe, to class the phenomena, and deduce the general results.

Arrangement of rocks on the surface.

It might be very excusable before Countries were cleared and cultivated, and before their various mineral productions were employed and understood, to imagine that the materials of the Earth were heaped together in confusion, the result of a chaotic formation; but at present, such a notion will not stand the test of a moment's reflection. One district has chalk beneath the surface, another limestone, a third coal, and a fourth granite, and these are never mixed or confounded together; so that the most careless observer must conclude that the different rocks are arranged after some ascertainable method. These different rocks are not mere insulated patches irregularly scattered through the country, but generally connected on the surface in long ranges, which in all the Eastern half of England have their prevailing direction from North-East to South-West. Thus the chalk of the Yorkshire Wolds is prolonged (see the Map of the British Isles) through Lincolnshire, Norfolk, Suffolk, Bedfordshire, Wiltshire, Dorsetshire, &c; the oolitic limestones range through Lincolnshire, Northamptonshire, Gloucestershire, and Somersetshire; and many other limestones and sandstones hold a parallel direction. Hence it happens, in proceeding from London toward the South-West, West, or North-West of England, we cross so great a variety of rocks, and so many ranges of hills.

A person proceeds from London to North-Wales. After passing low, gravelly plains in the drainage of the Thames, he climbs, by a long slope, the chalk-hills of Oxfordshire; crosses vales of clay and sandstone; ascends a range of oolitic limestone; traverses wide plains of blue and red marl; arrives in districts where coal, iron, and limestone abound; and, finally, sees Snowdon composed of slate. And if, in proceeding from London to the Cumberland Lakes, he finds the same succession of gravelly plains, chalk hills, clay vales, oolitic limestone ranges, blue and red clays, coal, iron, and limestone tracts, succeeded by the slate rocks, which compose the well-known summit of Skiddaw, will he not conclude that something beyond mere chance has brought together these rocks in such admirable harmony? Will he not have reason to conjecture that in the *interior* of the Earth regularity of structure must prevail?

Internal arrangement of rocks.

This conjecture becomes certainty when we explore the relative position of rocks as it is displayed in wells, pits, quarries, and mines, the works of human industry, or laid bare in cliffs and ravines by the hand of Nature. Here we see the rocks formed in layers or tabular masses of various thickness, but always of very great superficial breadth or extent and placed upon one another like the leaves of a book. These layers are called strata. Along the edges of hills, in the course of precipitous valleys, and by the margin of the sea, it not only is not difficult to recognise this truth, but it is almost impossible to avoid perceiving it.

Many parts of the English coast present what is termed a natural section of the rocks, and accordingly whoever visits the shores of Northumberland, Yorkshire, Kent, Hampshire, Cornwall, South-Wales, or Cumberland, may easily satisfy himself of the stratification of most of the limestones, sandstones, clays, and slates of England. For most of the cliffs are composed of several distinct layers of rock, which are piled one upon another in a regular order, preserve a definite thickness, and appear under the same circumstances in many distant places. In the interior of the country the same conclusion is to be drawn from examining precipitous hills and deep valleys; and even in the flattest country, Art supplies the means of investigation which Nature has denied. The wells, and pits, and mines, which have been found necessary for the comfort of civilized Man, all display the same general truth, and lead us to conclude that the principle of stratification among rocks is confined to no particular Country; but whether in the New or the Old World, in Continents or in Islands, it is so remarkable and so constant, that colliers sink deep pits, and miners undertake extensive levels, in full confidence that no exception to its generality will affect the result of their enterprises. It is not a speculative truth, but a practical law of Nature, and is probably the fact of most extensive influence in the whole Theory of Geology.

So many important facts respecting stratified rocks flow in together upon the observing mind, that it is not easy to analyze them in the exact order of their occurrence. A person attentive to the subject cannot fail to discover, even in a very limited district, that the different strata which appear above one another, like the leaves of a book, are also, like them, arranged in a certain constant order of succession. A stratum which in any one situation is found beneath another will never, in any other situation, be found above it.

Superposition of strata.

As a bookbinder sometimes neglects to bind in a particular leaf, so Nature sometimes omits a particular rock; but she never misplaces the rocks, as the careless workman sometimes misplaces his pages. Let us take, as an example, the cliffs on the coast of Yorkshire, between Flamborough Head and Robinhood's Bay. Gristhorp Cliffs are crowned by calcareous sandstone rocks, which rest on a thick, bluish, argillaceous bed; under this is a brown, ferruginous sandstone, and, still lower, a thin, calcareous layer full of fossil shells. In Scarborough Castle Hill, the same calcareous sandstone, argillaceous bed, brown ferruginous rock, and fossil bed, occur in the very same order of succession. Or let us station ourselves at Leeds, and examine the coal-pits of the neighbourhood, notice how many seams of coal are cut through, and what beds of sandstone and shale, and what layers of ironstone are met with. Then, inquiring of the workmen, we shall learn that the same "set of beds" is wrought at another pit. At this other pit we shall find the same beds of coal in the same order of succession, at nearly the same distances from one another, and of nearly the same qualities and thicknesses; and this strict analogy will be found at several pits over a considerable extent of ground, and, therefore, here, as well as on the coast, we obtain proof that in a limited district the *strata are arranged with respect to one another in a certain constant order of succession.*

Declination of strata.

Pursuing our investigation, we find that the strata are generally so disposed that their planes or broad surfaces are not exactly level or parallel to the Earth's spherical surface, but sloping in some one direction, so as, in that direction, to sink deeper and still deeper

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into the Earth, and to be covered by other strata. This slope, this deviation from the horizontal position, is called the dip or declination of the strata; and the rocks are accordingly *said to dip or decline* to this or that part of the horizon. The different rocks which compose the interior to a considerable depth are, therefore, in consequence of this declination, exhibited in succession on the surface, and hence it is that mankind is furnished with a vast variety of mineral productions suitable to its numerous necessities.

Continuity of strata.

Any one thus far initiated in Geology, and possessed of common powers of observation, will be able to compose a list or scale of the strata which occur in his own neighbourhood, *naming them* in the exact *order of their succession or superposition*, and thus will be furnished with the means of comparing his own district with others near and distant. The results of this comparison are very important, for we thus learn that one general order of succession is observed among all the stratified rocks of England. Certain strata are locally deficient, but all those which do occur together are found invariably in the same relative position. The series of stratified rocks in the North of England, taken in a general way, is expressed by the following names: chalk, gault, Kimmeridge clay, coralline oolite and calcareous grit, Oxford clay and Hackness rock, cornbrash and Bath oolite rocks, lias shales, red marl and sandstone, magnesian limestone, coal system, mountain limestone, slate. The series in the Southern parts of England is precisely accordant, except that the magnesian limestone is there nearly deficient, and that the Kimmeridge clay is covered by some strata which do not pass the river Humber. Besides, we find the strata of the North of England actually connected by mutual extension with those of the same names in the South of England, so that we thus prove their *continuity over large tracts*, as well as the constancy of the order of their succession.

By means of these comparative observations, begun by Mr. Smith in 1790, and continued with unabated zeal by his numerous disciples, the whole series of English stratified rocks has been ascertained, and arranged in tabular order; and the Geologists of England have, in consequence, furnished to the rest of the world a standard of comparison, by which to determine how far the laws of stratification disclosed in this Island are applicable to other Countries.

Stratification a general principle.

Considerable labours remain to be accomplished before even the stratified rocks of Europe can be completely compared with those of England, and the want of evidence is still more severely felt with respect to the three other quarters of the Globe. Nevertheless, the following important general results may be regarded as certain. The *principle of stratification* is found to be *universal;* that is to say, in every Country of sufficient extent, various rocks are found to be superimposed on one another in a certain settled order of succession, and these rocks are not found only in insulated patches, but often hold their course across Provinces and Kingdoms.

Throughout the whole area of Europe, from the Oural mountains to the Atlantic, and from Lapland to the Mediterranean, the stratified masses of the Earth, taken in their generalities, are arranged upon the same principles, follow one another in the same exact order of succession, and, in fact, form parts of one vast system of rocks, once more perfectly connected than at present.

What is known of the Geology of North Africa Egypt, Syria, the Countries bordering on the Caspian, Siberia, and Hindûstan, leads to a confident belief that the same general system, modified by local circumstances, will be found applicable to the greater portion of the surface of the Old Continent.

Analogy of distant deposits.

Important agreements between the strata of North America and New Holland and those of Europe, have been already determined, and the time will probably at last arrive, when, if it cannot be proved, as Werner perhaps imagined, that similar rocks were at the same time deposited in every part of the bed of the ancient sea, at least it will be possible to show that the same system of natural processes was every where in progress, contemporaneously or successively producing analogous effects; and to ascertain the relative antiquity and accompanying circumstances of even the most distant deposits; and thus to exhibit, in chronological order, a history of all the varied yet harmonious operations, by which, in regular gradation, this Globe was filled with long-enduring monuments of the everlasting power and wisdom of its Creator, and made fit to be inhabited by a Being capable of interpreting the conditional effects, recognising the appointed agency, and venerating the universal Cause.

Distinction of Stratified and Unstratified Rocks.

Relative situation.

Stratification is, therefore, the most general condition, or mode of arrangement of the rocks which appear in the crust of the Earth; and in the wide plains and gently undulated portions of the surface, it is often the only one discoverable. A person of good discernment, who should pass his whole life in investigating the South-Eastern part of England, or the Northern part of France, might conclude, from every observation he could there make, that the external materials of the Earth were *universally* stratified.

On the other hand, the inhabitant of the mountains sees so many examples of granitic rocks, totally devoid of any appearance of stratification, and sometimes finds that structure in the slate rocks so dubious and inconclusive, that he is wholly unable to comprehend the magnificent chain of inductions derived from the study of stratified rocks. Unstratified rocks generally abound along mountain chains and groups, and very often form their axis or nucleus. Stratified rocks fill the plains, and form the encircling flanks of the mountains. When a vast mass of unstratified rock, as granite, forms the nucleus of a mountain group, the stratified materials which surround it, generally slope away on all sides, as if the granite had been protruded from below these strata, and, during the act of its uplifting, had broken them, and caused them to assume their several inclinations. Other unstratified rocks, as basalt and porphyry, appear amongst the stratified rocks, sometimes in irregularly lenticular masses, as if they had been spread in a melted state around a common centre, sometimes filling long vertical fissures in the strata, as if they had been injected from below.

Mineral characters.

On comparing together the stratified and unstratified rocks, we find their mineralogical composition extremely different. The *stratified rocks* are earthy aggregates, as sandstones, clays, or simple Chemical precipitates, as limestone; such materials, in fact, as we know to be accumulated in the same mode of arrangement by modern waters.

The *unstratified rocks*, on the other hand, are gene-

rally and evidently crystallized masses, often analogous to volcanic products, or compounds containing essentially minerals which are not known to be producible from water, but in several instances are obtainable by artificial heat, or generated in the deep furnaces of which volcanic mountains are the vents.

Stratified rocks have evidently been deposited successively from above; the lowest first, the uppermost last, in obedience to the laws of Gravity.

Unstratified rocks, on the other hand, seem to be derived from the depths of the Earth, and to have been ejected or uplifted from below the strata, as volcanic matter is protruded at the present day.

Contents.

Stratified rocks contain very generally the remains of the plants and animals which were in existence at the period of their formation, exactly as remains of the present races of plants and animals are found buried in the modern deposits of water.

But unstratified rocks contain no such evidences of watery origin or mechanical aggregation.

Origin.

By all these characters, separately and comparatively considered, the two great divisions of materials which compose the external parts of our Globe, are proved to have been produced by entirely opposite causes. STRATIFIED ROCKS are analogous to the modern PRODUCTS OF WATER, and are therefore called Neptunian, while UNSTRATIFIED ROCKS are analogous to the MODERN PRODUCTS OF SUBTERRANEOUS FIRE, and receive the names of Plutonic and Volcanic, according to the degree and circumstances of this analogy

Mode of study.

The distinction now insisted upon, between the Neptunian and Plutonic formations, between stratified and crystallized rocks, is of the highest importance, and deserves the first notice, even on the very opening of the subject of Geology. For not only are these different classes of rocks distinguished by most important general characters, but even the methods by which they are to be investigated, and the preliminary knowledge required for this purpose are entirely distinct. Amongst the stratified rocks a knowledge of Zoology and Botany is required to develope the past history of innumerable remains of plants and animals, which were buried at successive periods; on the contrary, among the mountains associated with granite, where minerals of every hue and form appear in every different combination, scientific Mineralogy is of much higher importance.

In consequence, Geology divides itself into two branches, one of which links itself with the Natural History of modern plants and animals; and the other with Chemistry and Mathematics. And we have now, and have always had two distinct groups of Geologists, whose progress and discoveries have been as different as the preliminary knowledge which their different spheres of research required.

A Geologist of adequate attainments must indeed be supposed acquainted, at least generally, with both branches of this magnificent subject, and therefore a person entirely ignorant either of Mineralogy, on the one hand, or of Zoology and Botany on the other, must be considered as only half-educated. He may, indeed, be a very useful local observer, but he must be further instructed in his Science before he can be sent to explore an unknown region, or permitted to give an opinion on the whole Theory of Geology.

As much knowledge, therefore, as can be easily gained of the minerals which enter most frequently into the composition of rocks and veins, and of the Natural History of the plants and animals whose remains lie buried in the strata, is absolutely necessary to every professed Geologist. Yet on this account the student ought by no means to be discouraged; for this preliminary knowledge will be quickly, though insensibly, acquired by an intelligent observer, in exact proportion to his need of it. In a level country composed of limestone, sandstone, and clay, the multitudes of organic remains which continually meet his eye will infallibly procure him the power of discriminating their specific forms; and among the mountains associated with crystalline granite, the endless repetition of the objects will generate a Mineralogical tact in the eye, and a Mechanical if not Mathematical notion of the structure of crystals.

The summary observations which will be introduced in this Treatise on the preliminary Sciences of Zoology, Botany, and Mineralogy, will be placed with those divisions of the subject to which they respectively belong, and where they will be the most intelligible as well as the most useful.

On Stratification in general.

Strata, the term defined.

Strata, layers, and beds, are synonymous terms. "Strata," says Professor Playfair, "can only be formed by seams which are parallel throughout the entire mass." This definition, founded upon the supposition that loose materials deposited under water must be arranged in layers parallel to the surface of the water, undoubtedly contains the general or fundamental idea of stratification, but is often too abstract for practice. The most remarkably regular and parallel seams or divisions between the strata happen in calcareous and argillaceous rocks; but the partings in sandstone are much less uniform. A particular shelly bed of stone lies at the top of the coralline oolite of Yorkshire, and may be traced for a great distance; a red band, long since noticed by Lister, lies at the base of the chalk of Yorkshire and Lincolnshire for sixty miles in compass; the cornbrash limestone, seldom more than ten feet in thickness, is continuous from Dorsetshire nearly to the Humber. In these instances, therefore, Playfair's definition applies very well; on the contrary, the beds of sandstone with coal which are interposed in the oolitic system of Yorkshire, are altogether 500 feet thick near Robin Hood's Bay, but dwindle toward the South, and are entirely deficient before reaching the Derwent.

Such beds are therefore wedge-shaped  and cases sometimes occur where, by attenuation in all directions from the centre, they become lenticular. See pl. i. fig. 1. for these and other appearances.

Interposed strata.

The strata, therefore, are not all coextensive. Limestones are probably the most persistent and regular, sandstones the most limited and local. *Local* or *interposed beds* cause the principal differences between distant portions of the same formation.

The lias of England rests immediately upon red and bluish marly clays with white gypsum: at Luxemburg, they are separated by a thick sandstone. In the North of England, magnesian limestone separates the coal from the upper red sandstone, but in other parts of the Island these two formations are in contact. In the breast of Ingleborough, the limestone beds are aggregated into one vast mural precipice or scar; but as we proceed Northwards this mass opens to admit layers of sandstone, shale, and coal, which gradually increase under Crossfell, and swell out to a vast thickness in Northumberland, so as to contain several valuable seams

of coal, thick rocks of sandstone, and abundance of shale, between the horizontally separated beds of limestone.

The oolitic strata near Bath are composed of two portions, the upper or great oolite and the lower oolite, and between them is a series of calcareous and argillaceous beds called fullers' earth beds, sometimes 150 feet thick. As we proceed Northward into Lincolnshire, the fullers' earth beds are excluded from the series; still further North the whole series is changed; so that in Yorkshire it includes thick layers of sandstone, shale, and coal. On a first view the districts of Bath and Yorkshire are very unlike, but the contemporaneity of their disposition is certain from the continuation of the same oolitic beds through both of them.

Thickness.

The *thickness* of the Beds or strata varies exceedingly and seems to have reference to the rapidity, regularity, and continuity of the deposition and the rate of drying or consolidation of the materials.

The chalk rock is about 500 feet thick, and in all this great mass we can scarcely trace any decided beds; though the layers of flint at equal distances, (four to eight feet,) and the difference of the organic remains at different depths, evidently prove a succession of stratified deposits.

The great oolite near Bath is on the contrary divided into *a certain number* of beds, definite in quality, thickness, and order of position.

Laminæ.

A certain stratified rock, therefore, is composed of one or more layers or strata, but this is by no means the last term of the analysis. Each bed is often composed of many laminæ which are sometimes parallel to the plane of the bed itself, and sometimes lie in it at different angles. Thus micaceous laminated sandstones, and in particular the best flagstones of the coal districts, are composed of a multitude of thin layers parallel to the plane of the bed, and entirely covered by plates of mica which probably cause the splitting of the stone. This appearance is very analogous to the laminated sand quietly left by the successive floods of a river.

But the coarser flagstones of the same coal districts are often composed of laminæ, laid at various angles to the plane of the bed, and in consequence producing a rough, uneven, shattery surface, and a tendency to oblique fractures; thus, in pl. i. fig. 2. *a* represents the regular, and *b* the coarse, irregular flagstones.

Such appearances of oblique lamination are occasionally found in the modern sediment of agitated waters, both in the banks of rivers and on the sea-shore.

When these oblique laminæ extend through thick beds, they sometimes cause a slight difficulty in determining the dip of the strata, and are then called *false bedding*. Some of the coarse upper beds of the great oolite of Bath, Gloucestershire, Northamptonshire, and Lincolnshire, as well as of Normandy, are remarkable for this false bedding.

But it is in the coarse sandstones that we see the most remarkable examples of this structure, as on the Scarborough coast and under Nottingham castle.

The more violent the action of water, the less regular is the internal constitution of the layers found beneath it. Let any one with this view compare the effects of the tide beating upon the sand and pebbles of the Eastern coast, or the tumultuous products of a mountain river, with the tranquil deposit and sediment on the alluvial lands near Lynn and near Hull. In the former case, the materials are frequently found heaped together in laminæ, variously and confusedly inclined to one another; in the latter they are all parallel to the horizon, and to the general plane of the surface. The former case is exactly analogous to the false-bedding mentioned in a preceding section, so general in our sandstone conglomerates, and in shelly beds of oolite; the latter is exactly like the regular lamination of clays and shales. Like effects flow from like causes, and thus we are enabled to frame very plausible conjectures concerning the condition of the waters under which the several strata were accumulated.

General terms.

In the same way as a number of similar laminæ are sometimes united into one bed of stone, so several similar beds of stone, are sometimes associated into one rock, to which a specific name is applied, as the Oolite, the Lias Limestone, &c.

Sometimes several of these rocks are grouped under the title formation, as the Bath Oolite Formation. Thus in the lias limestone-beds, the lower lias clay, marlstone-beds, and upper lias clay, as represented in pl. i. fig. 3. are all included in the Lias Formation, which rests upon the Red Sandstone Formation, and is covered by the Bath Oolite Formations.

Series of British strata.

The following Table exhibits a complete view of the whole series of British strata, grouped according to their relative antiquity into three leading divisions, the Primary, Secondary, and Tertiary strata; it being understood that such divisions are chiefly adopted for convenience, as expressing with considerable accuracy certain general analogies of origin, composition, and organic contents, which prevail amongst the members of each division, but yet are not to be considered as exclusively belonging to them.

Two of these divisions are again subdivided upon exactly the same principles into systems of strata, which are marked by certain recurrent rocks, striking analogies of composition, organic reliquiæ of similar types, and positions derived from convulsions of the same epoch.

The systems are again usefully divided into formations; these into their several component rocks; whose ultimate analysis gives the strata, beds, and laminæ of composition. The superficial accumulations of gravel, sand, peat, &c., which are classed under the head of diluvial and alluvial deposits, are not included in this list of strata.

For the sake of the student to whom the mode of considering the sequence of rocks may not be familiar, the strata are here placed in the same order as they would be found on proceeding from the surface downward. This Table should be compared with that of Mr. Smith, p. 533, and of Werner, p. 531.

Tertiary Series of Strata,

partly lacustrine, but principally marine, sandy, and argillaceous, and with some calcareous deposits, abounding in shells and other organic exuviæ, closely analogous to existing species.

Formations.	Usual thickness of Formation. Feet.		Stratified Groups.
1. Upper marine formation	50		Sandy crag with shells. Zoophytic limestone.
2. Marinolacustrine	100		Upper freshwater limestone and marls. Intermediate marine bed. Lower freshwater limestone and marls.
3. Lower marine formation	1000 or more.	London clay group.	Bagshot sand. London clay.
		Plastic clay group.	Plastic clay, with coloured sands and lignites. Shelly blue clays and sands. Pebbly green sands.

Secondary Series of Strata,

principally of marine origin, with rare and local estuary deposits; consisting of repeated alternations of limestone, flint, sandstone, sand, clay, iron ores, coals, salt, &c., with organic remains generally very distinct from existing forms of animals and plants.

Cretaceous System.

Formation.	Thickness. Feet.	Stratified Groups.
4. Chalk	600	Upper soft chalk with flints.
		Middle harder chalk.
		Lower marly chalk.
		Red chalk.
5. Green sand	500	Green and grey sands.
		Gault clay.
		Iron sand or lower green sand.

Oolitic System.

Formation.	Thickness. Feet.		Stratified Groups.
6. Wealden			Weald clay and Sussex marble.
			Hastings' sands and limestones.
			Purbeck limestones and clays.
7. Upper oolite	400		Portland oolite and other limestones.
			Kimmeridge clay.
8. Middle oolite		Coralline oolite group.	Upper calcareous grit.
			Coralline oolite.
			Lower calcareous grit.
		Oxford clay group.	Oxford clay.
			Kelloway calcareous grit rock.
			Clay.
9. Lower oolite			Cornbrash limestone.
			Forest marble and sands.
			Great oolite.
			Fullers' earth, rock, and clays.
			Inferior oolite.
			Ferruginous sand.
10. Lias			Upper lias clay, or shale.
			Marlstone beds, sandy and calcareous.
			Lower lias clay, or shale.
			Lias limestone.
			Dark marls.

Saliferous System.

Formation.	Stratified Groups.
11. Variegated sandstone. (*Pœcilite, Conybeare.*)	Variegated marls, gypsum, and salt.
	Red and white sandstone.
	Red sandstone conglomerate.
12. Magnesian limestone	Red and white marls.
	Laminated limestone.
	Gypseous red and white marls.
	Magnesian limestone.
	Marl slate.
	Rothetodteliegende.

Carboniferous System.

Formation.	Stratified Groups.
13. Coal	Alternating.
	Sandstones.
	Shales.
	Coals.
	Ironstones, &c. resting on
	Millstone grit.
14. Mountain limestone	Alternating.
	Limestones.
	Shales.
	Gritstones.
	Seams of coal.
15. Old red sandstone	Conglomerates.
	Flagstones.
	Red and white marls.

Primary Strata,

containing organic remains, mostly of extinct tribes, and only in the upper part of the series.

Slate system, including many great divisions which eventually may be classed in formations, according to their organic remains and bands of limestone. It is *usual*, but vague classification, to distinguish this system into upper or fossiliferous, and lower, or non-fossiliferous slates and limestones.

Gneiss and mica schist system, including mica schist, chlorite schist, hornblende schist, quartz rock, primary limestone, gneiss, &c.

Granitic rocks, which are not stratified, usually form the basis of the strata, and are frequently but not by any means universally followed by the gneiss and mica slate system.

Disturbed Stratification.

Strata originally level.

All strata, says Cuvier, in his admirable "Discourse on the Revolutions of the Globe," must necessarily have been formed horizontal; and this opinion, founded upon the admission that rocks composed of regular layers, containing rounded pebbles, and organic remains of watery animals, can only have been formed under water, is supported by observation. For not only do we see at the present day the deposits of water arranged in planes nearly or exactly horizontal, but we also find the ancient strata of the Earth, where undisturbed by convulsions, very nearly level. In consequence of these disturbances the strata are seldom found to be perfectly horizontal, but are often inclined at high angles, and in a few instances stand directly vertical. Their planes are generally continuous over large spaces, but they are sometimes broken and dislocated by *faults or dykes*. It is now generally admitted that the usual horizontal disposition of the strata is derived from the action of the supernatant waters which accumulated them; and that the irregular declinations and fractures which we sometimes behold, are the effects of subterranean convulsions, chiefly occasioned by internal expansion. The truth of these opinions will appear from a few plain considerations.

Subsequently disturbed.

Earthy matter deposited from water by tranquil subsidence, as clay and limestone, or accumulated during periods of moderate agitation, as sand and sandstone, must in general be accumulated into layers or strata, proportioned to the intervals of deposition; and these layers, in consequence of the fluctuation of the water and the influence of gravitation, will especially tend to be horizontal. Nevertheless they must, in a considerable degree, accommodate themselves to the surface on which they are deposited. If the bottom be level, so will be the deposit; if sloping, the deposit will be inclined; but if there be a perpendicular subaqueous cliff, no deposit can fall upon its face, nor any transported materials be accumulated parallel to it. An originally perpendicular layer or deposit of earthy materials is obviously impossible. Whenever, therefore, we behold vertical strata, we may be quite sure that they were not deposited in that form, but have been displaced by some internal movements of the Earth. Abundance of instances of this remarkable position of strata may be quoted in almost any part of the World. The Isle of Wight gives us a magnificent series of strata 1100 feet in thickness, reared into an absolutely vertical position; and this effect is the more remarkable, because the materials uplifted consist of many strata of loose sands and pebbles which most certainly have been deposited level. In the Western borders of Yorkshire, vertical strata of limestone range for miles parallel to the edge of the Pennine chain, and turn Eastward through Craven, below Ingleborough and Penygant to Settle. Magnificent examples of vertical strata are familiar to those who have visited the cliffs of Savoy, or who have perused the graphic descriptions of Saussure.

Vertical strata.

Contorted strata.

There are some remarkable instances of contorted stratification very difficult to be explained without supposing the strata to have been soft at the time of the flexure. Not to dwell on inferior examples, we shall quote the magnificent phenomena of this kind which are seen in the valleys of Chamouni and Lauterbrun, and along the shores of the Lake of Lucerne, near Fluellen. The stratified limestones of these localities are bent into such extraordinary retroflexions, as to imply repeated operations of the most violent Mechanical agency, in different directions; and observations along the range of the Alps prove that the whole of this chain has been the theatre of enormous and reiterated concussions. (pl. i. fig. 4.)

Faults.

But the most remarkable case of disturbance is when strata, either horizontal or inclined, are broken, so that on one side of the line of fracture the rocks are much higher than on the other. This difference of level sometimes amounts to 100 or even 200 yards. The succession of strata is on each side the same, their thickness and qualities are the same, and it seems impossible to doubt that they were once connected in continuous planes and have been forcibly and violently broken asunder.

The plane of separation between the elevated and depressed portions of the strata is sometimes vertical, but generally sloping a little. In this case a peculiar general relation is observed between the inclination of this plane and the effect of the dislocation. In the diagram, (pl. i. fig. 5.) for instance, the plane of separation, $z\,z$, slopes *under the depressed*, and *over the elevated* portions of the disrupted strata, making the alternate outer angles $z\,z\,b$, $z'\,z'\,b'$ *acute*. In more than a hundred examples of such dislocations which have come under the notice of the writer of this Essay, he never found an exception to this rule. A similar law is found to prevail very generally in the crossing of nearly vertical mineral veins; for instance, (pl. i, fig. 6.) $a\,a$ are two portions of a metallic vein dislocated by another vein, $b\,b$. In this case the relation of the line $b\,b$ to the lines $a\,a$, is the same as that of $z\,z$ to the lines $a\,a$, $b\,b$, $c\,c$, &c. The contrary appearances, had they occurred, would have been as represented below; and such occur in the mining district of Cornwall together with many other singular phenomena, apparently referable to subterranean disturbance, perhaps complicated with other causes, but which are with difficulty reducible to any simple mode of explanation.

The line of dislocation is generally distinguished by a fissure, which is filled by fragments of the neighbouring rocks, or by basalt, and is then called a *dyke*; or by various sparry and metallic minerals, and is then called a *mineral vein*.

Relative age of the dislocation.

The irregular operations by which these disturbances and dislocations were occasioned, seem to have happened at various periods during the formation of the strata. We know, for instance, examples of horizontal strata, as $a\,b$ (pl. i. fig. 7.) resting upon highly inclined strata, $x\,y\,z$, which must have been forced into their unnatural position before the deposit of the level strata upon them.

Such a case occurs in Somersetshire, where the coal measures lie at a steep slope beneath horizontal beds of red marl. These coal measures are also greatly broken by *faults* which in some cases *throw* or elevate the beds on one side more than seventy fathoms above those on the other side. But the beds of red marl above are altogether uninfluenced either by the steepness of the dip or the abruptness of the dislocations. Therefore the convulsions by which these effects were occasioned, happened after the deposit of the coal seams, and before the deposit of the red marl.

At Aberford in Yorkshire, and at many other points along the line of the magnesian limestone between Nottingham and Sunderland, similar examples occur.

In such cases the discordance of inclination between the superior and inferior strata is expressed by the term *unconformity*, and the rock is said to lie *unconformably* upon the lower.

Principal epochs of convulsion.

By pursuing this investigation in different situations, we find that these internal movements or convulsions happened at intervals during the whole period of time occupied in the deposition of the strata. The most prevalent and remarkable cases of dislocation and unconformity are however observable: 1. immediately after the deposition of the slate series; (*Transition series* of Werner;) 2. after the accumulation of the coal system; 3. after the deposition of the oolitic rocks; 4. after the deposition of the chalk; and 5thly, one of the most recent probably of all, after the completion of almost all the formations above the chalk. It is not to be supposed that all even of these principal cases of dislocation can be recognised in every Country; on the contrary, the subterranean forces appear frequently to have shifted their points of action.

We shall have occasion to show, while speaking of the organic remains, that there is sometimes observed a singular harmony between these periods of extraordinary internal disturbance and the several epochas when the different races of animals and plants came into existence; and it is not unreasonable to suppose, that in this manner it may be hereafter found possible to establish such a relation between the internal and external condition of the Earth, as to afford the greatest assistance towards defining the agencies which have produced changes so extensive and repeated in both.

Proximity of mountains.

At present, restricting ourselves to the phenomena of elevation and disruption of the strata, we shall carry our inductions one step further for the purpose of proving what was before announced, *viz.* that these disturbances were connected with the effects of internal fires.

We shall assume then that granitic, and basaltic or trappean rocks, and others exhibiting the same phenomena, were crystallized from a state of igneous fusion, and were, sometimes in a fluid and sometimes in a solid state, impelled upwards from the interior of the Earth, as analogous substances are now raised fluid through volcanos, or lifted solid by earthquakes.

In proportion as we approach the mountains where the greatest violence was exerted to break up the strata, raise the granite, and inject the basaltic dykes, we find the dislocations increased in number and importance, and the confusion of the stratification more prevalent.

The central nucleus or axis of many mountain districts is a mass, or a series of masses of granite and other unstratified rocks, from which on all hands the strata are found dipping at high angles. In such cases there can be little room to doubt that the elevation of the mountain ranges and the disturbance of the strata, was occasioned by the same violence which uplifted the granite. See pl. i. fig. 8.

The area of granite disclosed between the opposite slopes of slate, is indefinite, sometimes very large,

sometimes very small, sometimes it is entirely covered over by the slate, which it has uplifted, but not perforated. The general analogy in the composition of mountains, in the strata which surround them, and in the dislocations which abound in their vicinity, prove that one common cause, the force of subterranean fire, has produced all the phenomena in question.

Basaltic rocks frequently, perhaps generally, show themselves in situations removed from the granitic regions, on the flanks of mountains and in lower ground. In numerous instances, basalt fills up the fissure between the elevated and depressed portions of dislocated strata, and as it cannot be doubted that such a fissure would soon have been filled up by other substances, it is clear that the melted basalt was injected nearly at the same time as the dislocation was produced; that is, that both were local effects of violent internal heat.

Analogy of mineral veins and trap dykes.

So great a general analogy prevails between some mineral veins and basaltic dykes, that in almost all hypotheses their origin has been assumed to be the same. Both in the same manner divide the strata; in both the materials are crystalline, generally such as are not known to be producible from water, and arranged according to entirely different laws from those which regulate deposits from water. It seems besides almost inconceivable that materials of such various Specific Gravity and Chemical affinities should be either soluble at once in water or capable of being introduced by this process at different times; on the contrary, all the circumstances agree in claiming for such mineral veins the same origin as basaltic dykes, the igneous origin of which is supported by the strongest possible arguments. We shall, however, discuss the history and origin of mineral veins more at large in the Chapter on Plutonic Products, and we shall then notice a variety of phenomena concerning them which can with difficulty be explained in the present state of our knowledge of Chemistry. That part of the history of mineral veins and metallic substances in general, which is inseparable from the consideration of the rocks in which they occur, will be treated of while speaking of the several strata in succession.

Disruptions of strata, a part of the general plan of terrestrial adaptations.

This elementary statement of the characteristic effects of subterranean convulsions upon the preconsolidated strata, must not be closed without noticing an important beneficial result of them upon the condition of mankind. The frequent use of the terms convulsions, dislocations, and other such phrases in Geological Treatises, may, perhaps, lead the inattentive reader to imagine that Geologists are of opinion that the laminated crust of the Earth, which had been constructed with so great harmony and order, was afterwards subjected to accidental injury, left to the violence of forces not contemplated in its formation, and the original plan of its fabric destroyed by unforeseen convulsions. How false a notion is this, and how unjustly would Geologists be accused of ignorance in this respect! They know well that without the effects, which are called convulsions and dislocations, the plan of the terrestrial creation would have been incomplete, the Earth not adapted, as it is, for the residence of men and the exercise of human intellect, which in all this seeming confusion can discern the progress of an uninterrupted plan, and even trace special provisions in favour of mankind. Whether we regard the mere animal nature of Man, or consider him with reference to those glorious endowments which lift him above the brute, and enable him to contemplate the past and anticipate the future, and thus to expand his intellectual existence through all periods and over all subjects, we shall find in the broken stratification of the Earth, the most remarkable attention to his Physical and Mental constitution.

Elevation of continents.

How universal are the benefits which are conferred on Commerce and the Arts of life, by the variety of substances obtained from the Animal Kingdom, cannot require to be stated; for without this variety, neither Commerce nor the Arts of life could exist. Some faint idea of the state of a Globe which did not show this variety, may be conceived by viewing the condition of the sandy deserts of Africa, and abstracting from their solitary desolation the assistance rendered by more favourably situated Countries. Now all that variety of mineral products existing in the Earth, stored up in that inexhaustible repository to supply many regions through many national revolutions, would have been made in vain, and for ever hidden from the eyes of men, but for these very convulsions and dislocations in the strata. What else has raised our mountains, divided our seas, and given currents to our rivers, and by so doing established upon the Globe those varieties of soil, local climate, and other conditions to which the organic wonders of Creation are most evidently adapted? What other means have been employed to produce the natural, harmonious, and mutually dependent relation of plants and animals on the land, in the streams, and in the sea? Without these disruptions, the Earth would still have been uniformly covered by shallow waters; or if some part rose above it, must have been a barren waste, or a monotonous surface on which the living wonders of Nature, according to the actual plan of Creation, could not have appeared. It is, therefore, evident, that as one of the means employed by the Creator in the accomplishment of his works, the agency concerned in producing the actual condition of the terraqueous surface, and thereby regulating the leading phenomena of organic and inorganic Nature, is a fit object for the special study of Geologists.

Exhibition of useful minerals.

It is not only in the elevation of continents, the varying height of mountains, the division of the sea, and similar striking effects, that we see the utility of the combination of subterranean igneous with superficial aqueous agency. Every coal-field in the known World proves distinctly the utility of even the minor dislocations, which in our imperfect language are called "faults" in the strata. The universal effect of these "faults" is to multiply the visible edges of the strata, by bringing them more frequently to the surface, in consequence of which there is, in the first place, the greater chance of discovering the materials of the Earth; and, secondly, the greater facility of working them. Other advantages of this kind will immediately suggest themselves to the attentive reader.

But all advantages to Commerce and the Arts of life sink into nothing when compared with the effect which the Human Mind experiences from contemplating the monuments of past conditions of the Globe, which the uplifting of the bed of the sea, and the dislocations of the strata, have brought to light. All Nature is a glorious book, which men are incited to read, in order to know and communicate with its Author, a mirror in which the Almighty and the Infinite is faintly typified in the vast and the diversified; and in this respect, Geological monuments are distinct, impressive, and, in reference to the earlier epochs, unique. But, if we have been conducted by long labours to some real knowledge of the internal constitution of the Globe,

and familiarized with the conception of many revolutions of created Beings on its surface, in accordance with a long sequence of Mechanical and Chemical operations; and if we have thus extended the conviction of the unceasing care and comprehensive benevolence of the Divine Being to the most remote epoch which our limited intellect can reach; all this is owing, in a certain sense, to the convulsive movements originating below the crust of the Earth. Let it not, therefore, be supposed, that, because of the contracted scale of the Human Mind, which can see only in succession what to a greater Intelligence is contemporaneously evident, Geologists are obliged to speak of certain phenomena as *accidents* with reference to others, which are connected therewith by ways unknown to us, that they are so blind as not to see in all the diversified operations of Nature, the effects of One predisposing and directing Cause.

Internal Structure of Rocks.

Joints in different rocks.

All rocks, whether stratified or not, are naturally divided by fissures, passing in various directions, independent of the strata, into masses, which are of different form in dissimilar rocks, and are accompanied by circumstances deserving more attention than has yet been bestowed upon them. The fissures or planes of parting between these masses are called *joints*. Most frequently their direction is nearly vertical to the planes of stratification, where such exist, and they divide the rock into cubical, rhomboidal, or prismatic portions, blocks, pillars, or columns. It is owing to their various direction and frequency that different rocks assume such characteristic appearances, and may thus be often and readily distinguished when seen at a distance or shadowed in a drawing.

Some rocks have very numerous, approximate, and closed joints, as shale, some kinds of slate, and laminated sandstones; in others, as limestone, the joints are less frequent, and more open.

In coarse sandstones, they are very irregular, so that quarries of this rock produce blocks of all sizes and forms. From this cause, coarse sandstone rocks show themselves against the sea, in precipitous valleys, or on the brow of hills, in rude and romantic grandeur. The wild scenery of the Peak of Derbyshire, Brimham Crags, and Ingleborough in Yorkshire, derives attractive features from the enormous blocks of millstone grit; and the magnificent rocks which stand upon the hills and overlook the Vale of Wye, are composed of a somewhat similar material.

In clay, vertical joints are numerous, but small and confused, whereas in indurated shale they are of extraordinary length, very straight, and parallel, dividing the rock into rhomboidal masses. This may be well studied in the shale, which alternates with mountain limestone, at Aldstone Moor in Cumberland. Rhomboidal joints are frequent and very regular in coal.

In limestone the vertical joints are generally regular, and arranged in two sets, which cross at nearly equal distances, and split the beds into equal-sized cuboidal blocks; and thus the mountain limestone is found to be divided into vast pillars, which range in long perpendicular scars down the mining dales of the North of England.

In slate districts, the joints, more numerous and more regular perhaps than in any other known rock, have almost universally a tendency to intersect one another at acute and obtuse angles, and thus to dissect whole mountains into a multitude of angular solids, with rhomboidal or triangular faces, which strongly impress upon the beholder the notion of an imperfect crystallization, produced on these argillaceous rocks since their deposition and consolidation, by some agency, probably heat, capable of partially or wholly obliterating the original marks of stratification.

Vertical joints are frequent in granite, and appear to have definite directions. The trihedral and polyhedral vertical prisms of basalt, and some other igneous rocks, coupled with their regular transverse divisions, seem to give us the extreme effect of regularity in the division of rocks by the process of condensation, from the state of igneous or aqueous expansion.

General cause of joints and fissures.

That contraction after partial consolidation of the mass is the general immediate cause of the numerous fissures of rocks, may easily be proved by a variety of facts observed in conglomerate rocks, where pebbles, and in others where organic remains are *split* by the joints, but cannot surely require argument. According to the circumstances of the case, this process has produced in basalt, slate, and coal fissures so regular as to give to the rock a largely crystalline structure, but left in sandstone mere irregular cracks.

From Mr. Gregory Watt's experiments on fused basalt, and some other notices by different authors, we know that a continued application of even moderate heat to a previously solidified body, may be sufficient to develope in it new arrangements of the particles, new crystalline structures, new Chemical combinations, and to cause a real transfer of some of the ingredients from one part of the mass to another; from many independent facts it is inferred, as a matter of certainty, that all the strata have locally, and the lower ones perhaps universally, sustained the action of considerable heat, since their first deposition: we seem, therefore, to be possessed of the clue which is eventually to conduct us to a thorough knowledge of the cause of the different structures observable in rocks independent of their stratification.

But though heat be taken as the leading cause of these effects, it is by no means inconsistent to suppose that some other independent agent, as, for example, Electricity, might be concerned in modifying the result. From all the recent discoveries in Electricity, it appears more and more certain, that this universal agent is excited in every case of disturbance of the Chemical or Mechanical equilibrium of natural bodies, and it is especially, and very sensibly, excited by unequal distribution of heat. Professor Sedgwick's suggestion with reference to Mr. Fox's electro-magnetic experiments on the mineral veins of Cornwall, that Electricity was probably concerned in the original production of those veins along which it now circulates, may be justly extended to the joints of rocks; in the study of which the writer of these remarks has found abundant reason to believe that the theory of the production of mineral veins is inseparable from that of the joints and fissures, in *some of which* the metallic substances are deposited.

Direction of fissures.

In examining with attention a considerable surface of rock, it will be found that amongst the joints are some more open, regular, and continuous than the others, which occasionally stop altogether the cross-joints, themselves ranging uninterruptedly for some hundreds of yards, or even far greater distances. There may be more than one such set of long joints, and, indeed, this is commonly the case, yet, generally, there is one set

more commanding than the others, more regular and determined in its direction, more completely dividing the strata from top to bottom, even through very great thicknesses, and through several alternations of strata. For example, there is a peculiar character of joints in each of the principal strata of the mountain limestone series, limestone, sandstone, shale, and also in the sandstones, shales, and coal of a coal district, yet, throughout the whole of Yorkshire, all these rocks are divided by the *master-joints* passing downward through them all in nearly the same direction North by West, and South by East. These master-joints, called *slines, backs, bords*, &c. are perfectly well known to the workmen, as well as some other very important yet less certain and continuous fissures passing nearly East North-East and West South-West. It is according to such joints that the experienced collier arranges his workings, and the slater and quarryman conduct their excavations. Now surely nothing can be more certain than the inference, that some very general and long-continued agency, pervading at once the whole mass of these dissimilar and successively deposited strata, was concerned in producing this remarkable constancy of direction in the fissures which divide them all. The utter deficiency of recorded observations prevents any further illustration of this important subject by reference to other districts, but it is obvious that a great principle in the construction of the Earth is here indicated, which must eventually have an important influence on Geological Theory. In the mean time we may remark, *first*, that these prevalent directions of North by West and East North-East, are those of the principal *mineral veins* and cross courses in the North of England, and that they are also admitted to be very prevalent in the Southern and Western mining Countries; *secondly*, that these directions are wholly uninfluenced either by the *declination* of the strata, or by the numerous *dislocations* to which they are liable. Whatever be the direction of the dip, how frequent soever the faults, the lines of the great joints are the same. These lines are frequently the cause of particular courses in rivers, long scars on mountain sides, and subterranean channels for water. Faults, and dykes, and mineral veins very frequently pass along them, and there is little doubt that the diligent study of them will be found to throw a new light on some of the most mysterious phenomena of Geology. See pl. i. fig. 9.

In a recent Paper on the cleavages of granite in Cornwall by Mr. Enys and Mr. Fox, these cleavages are proved to follow certain lines of *definite* direction, like the well-known cleavages of slate.

Local changes of internal structure.

Though a little out of place, we cannot forbear to add here a short notice of facts known in Swisserland, which distinctly prove one of the effects of heat upon common argillaceous shales, to be the alteration of its structure, so as to give a real vertical cleavage to a mass of horizontal laminæ of clay, as well as that induration which belongs to slate. The lias shales of the Alps are so altered by proximity to the igneous rocks of that region, that in several places in and near the Valley of Chamouni, they are commonly mistaken by modern tourists for genuine slates of the primary system, and were always described as such by the older writers. How plainly does this teach us that the joints, cleavages, and other peculiarities of their structure, not produced in rocks by water, nor coeval with their deposition, have been occasioned chiefly by the agency of subterranean heat. What powerful aid does this generalization give toward explaining many phenomena heretofore despaired of in Geology.

Mineral Composition of Strata.

Water is both a Chemical and a Mechanical agent. Under different circumstances at certain temperatures, by the help of other ingredients, as acids or alkalies, various mineral substances are dissolved in it. When, by evaporation, loss of heat, or a change in the composition of the liquid, these substances are no longer capable of remaining in solution in it, they separate in a crystallized form, or fall down, and the sediment which they occasion is called a precipitate.

By such processes lime, magnesia, and other earths and metallic oxides, are first dissolved in water, and afterwards separated from it. We find these processes, in the present order of Nature, chiefly concerned in producing calcareous marls and irregular accumulations of limestone, in lakes and in the course of certain streams and at the mouths of some rivers. So in more ancient times, the most abundant Chemical deposit from water was limestone.

The *Mechanical agency* of water is manifest at the present day in removing materials from one place and accumulating them in another. Thus pebbles and sand and clay are transported by the tides and by rivers, and accumulated in low situations in regular layers, miniature representations of those thicker strata of the same ingredients, which compose the crust of the Earth. And as at the present day some materials are transported further by water than others, and consequently more rounded by attrition, so the materials of the interior strata are likewise more or less worn and rounded, in proportion to the distance they have travelled and the friction they have suffered.

In many situations Chemical and Mechanical products are occasioned successively by the same waters, just as, in the older strata limestones and sandstones alternately prevail. We see, therefore, that the ancient deposits from water, which form layers several miles thick around a great part of the Globe, are not essentially different, except in degree, from the lesser deposits now formed beneath the tides from the sea and the streams from the land.

The Chemical stratified deposits are principally limestones, composed of carbonates of lime and magnesia, and salt rocks characterised by muriate of soda. This is not the place to discuss points of Theory, and we shall therefore speculate no further at present on the origin of these deposits than to say, that if by any means a large supply of an alkaline carbonate, as carbonate of soda, for instance, was diffused through the sea, the effect would be a precipitation of carbonate of lime and carbonate of magnesia, which would be accumulated into strata upon the bed of the sea in thickness proportioned to the quantity of the muriates decomposed, while the supernatant liquid would be found highly charged with muriate of soda, or common salt. If the alkali were only locally diffused, the deposit would be contracted, if generally, the strata might be very extensive.

The *Mechanical deposits*, or strata, composed of earthy materials, are distinguished by the coarseness or fineness of the ingredients and by the nature of these ingredients. When the materials are of unequal fineness, and some of them are large, rounded pieces, the rock is called a conglomerate; pieces not so large constitute a sandstone, very fine particles clay. The fol-

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lowing scale will convey some notion of the gradations of size in the ingredients of Mechanical deposits.

Very fine particles generally containing 20 to 30 parts of alumine	Clay, marl, shale, and slate.
Mixture of clay and sand	Sandy clay.
Sand with some clay	Argillaceous sandstone.
Small fragments of hard silicious minerals..............	Sand, sandstone.
Sandstone including pebbles ...	Millstone grit.
Large pebbles united by sandstone or clay	Conglomerate, or puddingstone.
Pebbles disunited.............	Gravel.
Stony fragments reunited	Breccia.

Ingredients of mechanical strata.

Considered with reference to the *nature* of the ingredients which compose them, Mechanical strata form another scale.

Thus gneiss, one of the oldest of these strata, is a compound of the same ingredients as granite—quartz, felspar, and mica; but these minerals, instead of being amalgamated (so to speak) together by crystallization, are accumulated in successive laminæ more or less regular. Gneiss, therefore, differs from micaceous sandstone much less than is commonly imagined, and often has no other permanent distinctive character, than that presented by the peculiarity of its composition.

Sandstone is generally an aggregate of small fragments, or worn crystals, of quartz, with or without any argillaceous, or calcareous, or irony cement in the interstices, with or without any mica in the partings. Sometimes it very evidently contains rolled and broken pieces of crystallized felspar, such as fills the Pyramids around Mont Blanc, or the granite of Cumbria and Scotland. There is, therefore, every reason to conclude, that coarse sandstones like the millstone grit, as well as gneiss, have been derived from the waste of ancient tracts of granite.

Some beds of sandstone at Oban in Argyleshire appear to have been formed from the granular fragments of disintegrated greenstones. Sandstones sometimes extend over vast districts, and during the whole range are characterised by some remarkable mineral ingredient; as for instance, the green sand of England, France, and Swisserland, which is distinguished by the presence of a peculiar green mineral. (Glauconite.)

Conglomerates, on the other hand, are generally constituted of fragments from the neighbouring mountains. Thus the red sandstone of the Vosges mountains contains quartz pebbles derived from the slate rocks of the vicinity; the old red conglomerate of England varies in its composition according to its locality; that of Herefordshire contains much quartz, that of Cumberland is filled with pebbles of slate.

Whole series of strata.

The whole series of stratified rocks then consists of alternate deposits of limestone, sandstone, and clay, with few layers of coal, rock salt, flint, iron ore, &c. The modes of alternation are different in different parts of the series, and in different situations. Thus what is called the transition limestone is enclosed between beds of slate, the carboniferous limestone alternates with sandstone and shale, the lias limestone lies in marly clays, the coralline oolite is enveloped in calcareous sandstone. Generally, the different strata are distinguishable by their mineralogical characters; but not always. When the circumstances of the deposit were nearly similar, as in the accumulation of the carboniferous limestone and some of the oolites, the strata are remarkably alike; and often particular beds of one rock are scarcely to be distinguished from beds of another rock. Thus some beds of lias are scarcely to be known from some calcareous layers connected with the Bath oolite, while other portions of the same rock strongly assimilate to the carboniferous limestone. The old red sandstone and the new red sandstone formations are very much alike; it would be difficult by mere mineralogical methods to discriminate the clays which separate the oolites, and many sandstones of very different epochs are almost undistinguishable. Hence we may infer that nearly the whole series of strata is the result of many repetitions of similar Mechanical and Chemical agencies operated by the same waters.

Alternation of beds.

When sets of strata are in contact, as for instance limestone lying upon sandstone, it often happens that while the limestone above, and the sandstone below, are unmixed with other matter, there is a middle set of beds composed of alternate layers of the sandstone and limestone. Thus let a be the coralline oolite of England, and b calcareous sandstone beneath; the middle beds $a' a'' b' b''$ are alternately oolite and sandstone. See pl. i. fig. 10.

In such a case, therefore, the two strata are said to *exchange beds*, or to be subject to *alternation* at their junction, and the phenomenon seems to have been occasioned by temporary cessations of the deposit of sandstone during the commencement and progress of the deposit of limestone.

Gradation of beds.

In other instances the two strata *pass into one another* by imperceptible *gradation*; as for instance, the Oxford clay of the Yorkshire coast graduates into the calcareous grit above so completely, that the bluish colour of the crumbling shale below is shaded off without any hard line into the yellow solid beds of grit above. See pl. i. fig. 11.

In either case it seems quite evident that no considerable break or interval of time happened between the different contiguous deposits, one bed was no sooner formed than another was laid upon it; and by careful study of these phenomena it appears that, bed by bed, and rock after rock, the whole series of strata even to miles in thickness were successively and almost unremittingly accumulated, and buried the shells and other organic Beings, which were then living in the water, or drifted into it from the land; such are, therefore, the best witnesses of the lapse of time, and of the changing condition of the land and water during the deposition of the strata.

Proportions of Chemical and Mechanical deposits.

Assuming limestones to be Chemical, and sandstones, clays, &c. to be Mechanical deposits, and putting for the present out of consideration the organic remains, which so much abound, especially in calcareous strata, we shall be able by comparison of the thickness of the several rocks to present a tolerably accurate notion of the relative proportions of Chemical and Mechanical deposits. The greatest obstacles to accuracy exist amongst the primary strata, whose thickness is exceedingly uncertain, and indeed often hardly to be determined at all.

If we take our examples of these strata from the Island of Great Britain, it may, perhaps, be found a sufficient approximation to the ratio now sought to say the Mechanical to the Chemical deposits of water are:

In the Primary Series, as	500 : 1
Carboniferous System....	10 : 1
Saliferous System	5 : 1
Oolitic System	4 : 1
Cretaceous System	2 : 1
Tertiary System.........	10 : 1

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From this comparison it would appear that the ratio of Chemical to Mechanical strata is greatest amongst the secondary deposits, andj least amongst those of the primary periods; a circumstance on which depend principally the well-marked general characters of the secondary series of rocks. It should, besides, be observed, that calcareous matter very finely divided exists in nearly all the sandstones and shales of that series, and sometimes so abundantly as to change, locally, lias shale into argillaceous limestone, and calcareous grit into arenaceous limestone, or coarse oolite. In secondary strata, the great preponderance of limestones almost invariably attracts the attention and directs the classification, and thus it happens that while numerous layers of clay and sand pass nearly unobserved, or are merely noticed as *interpolated beds*, almost every calcareous bed has its characteristic local name. The almost universal diffusion of calcareous matter through the mechanical strata of this large class, combined with the greater regularity and persistence of the limestones, generally impresses on the attentive observer a peculiar theoretical notion as to the cause. He soon learns to consider the operations by which sandstones and clays were accumulated as of short duration, and intermitting action, like the periodical floods of a river, or some less regular inundations; while the production of limestone is regarded as the result of one continuous and almost uninterrupted series of Chemical changes. This opinion, strengthened by the curious gradations between the calcareous and the sandy or argillaceous laminæ, and by the frequent alternation amongst even their thinnest portions, derives very plausible arguments from the distribution of organic remains through the several strata. In some cases these teach us plainly that sandstones, even of great thickness, were the products of temporary and often of very local floods, which swept down from the land the scattered spoils of the animals and plants then in existence; but, tried by the same tests, the calcareous rocks appear to have been of slower and more equable production, in clearer and more tranquil waters. Is not this exactly in harmony with the present system of natural operations?

Condition of Organic Remains.

What organic remains occur in the Earth.

The fossil remains of ancient plants and animals have been the theme of admiration for the learned and the vulgar in every Historical Age. The difficulty of understanding how the shells of the sea and the plants of the land could be inclosed in hard rocks, in prodigious abundance and of exquisite beauty, led Plot and Llwyd, and even partially Ray and Lister, together with some continental writers of eminence, to adopt a most strange hypothesis. Plot advanced the extreme absurdity that these beautiful monuments of the ancient condition of the Earth had in fact never been shells or plants, but were merely *lusus naturæ*, deceptive resemblances produced by some plastic power in the interior of the Earth. Swift well ridicules this notion of *lusus naturæ* in his Voyage to Brobdignag.

This ridiculous fancy has long since become obsolete, and the "formed stones" dug out of the bowels of the Earth are now recognised as the original inhabitants of its primeval land and water.

The differences of condition between them and analogous living objects, the mode of their conservation, the manner of their distribution in the Earth, the relative periods of their existence and destruction, constitute a vast, lucid field of research, through which many avenues are already traced toward the secret powers which presided over the formation of the Earth.

Terrestrial Plants abound in certain strata, especially in the coal districts, where the seams of coal are nothing but vast layers of vegetables swept down into estuaries or lakes, and there covered by sand and clay, and changed by Chemical depositions.

Zoophytes both stony and flexible, many of them belonging to genera now in existence, fill our limestone rocks with their most delicate and beautiful organization; with them lie abundantly columns of crinoidal animals, and crusts and spines of echini.

Molluscous Animals are now the most numerous of all the tribes of Beings which overspread the bed of the sea, and their shelly coverings are also the most abundant of all the organic fossils.

Of the Articulated Animals, the most abundant remains are lobsters and crabs, and other crustacea, analogous to existing types; besides trilobites and others to which nothing similar has yet been found in the modern ocean. Fossil insects are very rare; and confined to almost a few comparatively recent deposits from fresh-water.

What portions of the original structures are preserved.

No one acquainted with the structure of the invertebral Animals previously mentioned, can view their crusts, shells, and other hard appendages in the fossil state without being struck on the one hand with the wonderful perfection of all their minutest organization, and on the other with the uniform and almost total absence of their soft parts. The bodies found "petrified" in the rocks were originally durable. Similar substances are now capable of conservation in our cabinets: but the softer animal parts which they protected—the muscles, the viscera, and even the ligaments—have almost uniformly disappeared. Hence it appears a just conclusion that the process of petrification, the substitution of mineral for animal matter, was slow and gradual.*

The same result follows a similar examination of the fossil reliquiæ of vertebral Animals. For though we find in tolerable plenty the bones and teeth of fishes and reptiles, the skin and other softer parts are usually deficient. The bones of birds are excessively rare, and those of mammalia are mostly confined to the least ancient of all the Neptunian deposits.

In what state imbedded.

In consequence of this decay of the softer parts, many of the hard parts of Animals are found disjointed and separate. Crusts of lobsters, bivalve shells, vertebral columns, originally bound together by perishable ligaments, are very generally found in detached portions, precisely as happens to similar objects at the present day; and generally this is all the injury they have sustained. The delicate striæ, sharp spines, and other ornaments, are usually so well preserved that no one can believe that they were ever removed far from their native haunts. They were, in fact, quietly buried on the bed of the sea; living or dead, entire or decomposed, just as such Beings are found at the present day, when by any method the bed of the sea can be examined.

And just as at the present day where currents run strongly in the sea, shells are worn by friction in the

* The ligament of *Cardium truncatum* is preserved in marlstone at Rosebury and Staithes in Yorkshire, and impressions of the *Arms of Cephalopoda* are found in the oolite of Franconia.

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sand and by beating against one another, and trees carried down by rivers are scattered in fragments; so in certain of the old strata we find similar proofs of rapid currents from the land, and temporary turbulence in the primeval ocean.

All the accidents of imperfection and disunion of parts happened, of course, before the organic bodies were enveloped in the earthy deposits.

Subsequent changes of composition.

The changes by which they have been converted to petrifactions did not, probably, commence till after they were thus enclosed.

These changes in the substance of the fossil reliquiæ are different according to the original nature of these bodies, the kind of matter in which they are enveloped, and the other circumstances by which they were surrounded.

We shall make some remarks on the conservation of the principal classes of organic fossils in the different kinds of matter.

In plants.

Dried vegetable substances may be considered as compounds of carbon, oxygen, and hydrogen, with small and variable proportions of other substances.

Carbon	40 to 55 per cent.
Oxygen......	40 to 50
Hydrogen	about 5

Of these ingredients the most volatile parts, *viz.*, the oxygen and hydrogen, seem, in many cases, to have vanished, but the carbon generally remains, and is either almost pure, as in some kinds of coal; mixed with bitumen, as in jet and most coals; mixed with carbonate of lime, as in the remains of coniferous wood in the lias and oolite; or blended with flint or pyrites in those and other strata. Generally, as might be expected, the vegetable substance is most completely disguised by earthy admixtures in porous strata, such as oolite or sandstone; and, on the other hand, the original carbonaceous skeleton of the plant is preserved with the least change in close, compact materials like clay, shale, or ironstone. This is strikingly exemplified in the coal-districts, where ferns and other plants which lie in the shales are changed to bright inflammable coal, while the very same species in coarse gritstone are represented only by a brown, ferruginous stain. Coal is most evidently a product on a large scale, precisely identical with the thin filmy remains of ferns and reeds which accompany it. A vast mass of plants accumulated beneath the ancient sea, or in sea-like lakes, was covered up and buried by successive deposits of sand and clay, and under this heavy pressure, and hermetically sealed, Chemical decomposition went on, and a new Chemical product, coal, was elaborated; which, upon analysis, is found to contain the usual ingredients of vegetables, in proportions no otherwise different than was to be expected from the loss of some of the more volatile parts.

In this respect, coal exhibits many variations. That of Kilkenny, for instance, has only four per cent of volatile matter; Cannel coal has about fifty per cent.; the Kilkenny coal contains ninety-two per cent of carbon, common coal about seventy per cent. carbon, and thirty per cent. oxygen and hydrogen.

In corals, shells, crusts.

The internal and external hard parts of invertebral animals, zoophytes, mollusca, and articulosa, are much allied in composition. They generally contain the same durable and the same perishable parts; carbonate of lime, alone or with a small admixture of phosphate of lime, gives them firmness, and the flexibility which some of them possess is derived from gelatine.

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The process of petrification consists in the loss and replacement by a different substance of one or other of these ingredients. The first degree of change which these fossils have experienced, is when the coralline or shell retains not only its external figure and appearance, but even its internal texture, and almost all its original substance. Such specimens look as if obtained from the sea-shore in a dead state, with no other apparent loss than that of colour and brilliancy. This state of conservation may be said almost to characterise the organic remains of the strata above the chalk.

Loss of colour, &c.

The next step in the process of petrification is illustrated by many shells which lie in the gault and other clays; they have lost their gelatinous portion, and are, in consequence, become light and friable, but have not received into their pores any extraneous earth.

Loss of gelatine.

The third variation is occasioned by the gradual substitution of an extraneous substance, as flint or pyrites, into the pores left by the decay or waste of the original body; thus the fibres of wood and sponge, and the plates of corallines and shells, have been changed by little and little into a different substance, which often represents with most faithful accuracy the minutest structure of the original. It is evident, therefore, that this great change was accomplished gradually, the new particles taking successively the place of those removed by decomposition.

Insinuation of new matter.

These processes of decomposition and substitution of new ingredients, which probably commenced at the periods when the several fossils were imbedded in the rocks, are to this day continued, and often exhibited with remarkable energy. Those products of modern operations of Nature which go under the vague name of recent petrifactions are so various in their character, that a detailed study of them, in relation to their accompanying circumstances, could not fail to furnish data for explaining some of the most remarkable stages in the process of mineralization, to which organic bodies have been exposed in the Earth. In proof of this, we shall content ourselves at present with putting in comparison a well-known peculiarity in the mode of conservation of certain fossils, and an instance of the same singularity in recent petrifactions. It is often to be noticed that while the external cell of an ammonite, or the larger part of the spiral cavity of a melania, is filled by the coarse matter of the enveloping rock, the closed chambers of the former, and the smallest volutions of the latter, are filled with crystals of calcareous spar. The well-closed shells of productæ, terebratulæ, &c. are often lined internally with calcareous spar, quartz, or even galena, while this never happens, perhaps, to shells whose valves did not fit very exactly. In fossil wood it happens very often that the external parts are merely jet or coal, while the central portions are changed to carbonate of lime; and, in general, all these examples appear to agree in proving that the mineralizing substance was transferred to its repository in the innermost cells and smallest pores by a kind of secretion, quite through solid septa of shell, and considerable thickness of even dense stone. The recent petrifactions of hazel-wood and nuts, from the alluvium of Ferrybridge in Yorkshire, (*Phil. Mag.* 1828,) prove that the same remarkable transfer of particles through other substances, with the same elective attraction for these particles possessed by the finest textures and smallest cavities, accompany the ordinary modern aqueous deposits of carbonate of lime. In the alluvium of

Analogous modern processes.

this place, a certain part of a large collection of hazel-wood and nuts was found mineralized by a subterranean spring from the neighbouring limestone, and it was remarkable that the central woody core of a hazel-branch or root was wholly converted to stone, while the bark and outer layers of wood were unchanged, the kernel of the nut was petrified within its brown unaltered membrane, and the internal fibres of the shell within the still woody surfaces.

Dissolution of shells, corals, &c. The fourth condition is exemplified in limestone and sandstone rocks, from which the whole of the substance of shells, corals, &c., has been dissolved and carried away by water. In consequence, a cavity is left in the rock bearing the *impression* of the exterior of the shell or coral, and in this cavity is a *mould* or *cast* of the interior. Thus the "screwstones," as they are called, have been cast or moulded in the cavities of crinoidal columns.

Replacement of shells, corals, &c. The most extreme case of mineralization or petrifaction is produced by a process in addition to that just described, when the cavity left by the removal of the shell or coral is again filled up with crystals of calcareous spar, deposited by water filtrating through the stone. Sometimes, only a few crystals connect the inner mould or cast to the exterior impression, but generally, the whole cavity is filled by the spar, which thus represents truly the shape of the original body, but displays no trace whatever of its internal texture.

Dependence of these changes on the nature of the rocks. There is in general a certain accordance and relation between the condition of organic fossils, and the nature of the rock which incloses them. In the green sand almost all the shells are silicified, in the oolitic rocks many are changed to calcareous spar, in the clays very slight changes have happened to any of the organic remains.

On the other hand, the original nature of the organic substance has very much influenced its mode of conservation. Echinidal and crinoidal remains are almost invariably converted to a peculiar kind of opaque, calcareous spar, in whatever strata they occur; gryphææ and astrææ retain their laminæ, inocerami and belemnites their fibres.

Remains of vertebrata. We come now to the vertebral division of Animals. Their soft portions have perished, but their teeth, bones, and scales remain, either connected or separated in consequence of the decay of the ligaments, cartilages, &c.

The hardening ingredient of bones is principally phosphate of lime, that of teeth is a mixture of phosphate and carbonate of lime. It is generally the fact that their gelatinous or membranous portion has been diminished, and their earthy admixture increased, by the subterranean Chemistry to which they have been subjected, and, in consequence, their Specific Gravity is much augmented.

Distribution of Organic Remains.

Number of species. The researches of modern Naturalists have been singularly successful in bringing to light a vast number of new species or supposed original types of organization. The catalogues of living plants and Animals have been enormously lengthened in consequence of more rigorous investigations among the smaller tribes. In like manner the number of known organic fossils has been of late year[illegible] greatly augmented, that in some departments the[illegible]ly equal, and, in others, exceed the living ranks of [illegible]tion. In Great Britain alone, 1500 species of organic remains have been well described and figured; and it is probable that the numerous tribes of undescribed zoophyta, mollusca, crustacea, and plants, will swell the catalogue to 2500 species at least. An equal number of other kinds adorn the cabinets of Continental Europe. Generally speaking, the principal deficiencies in the catalogue of fossils, as compared with that of living organic forms, are found in the aerial and terrestrial races.

Insects, birds, land reptiles, and mammalia are the rarest of fossils. We are, however, not to conclude that the ancient land was uninhabited by those tribes, because we do not find their remains in the strata which were formed on the bed of the ancient sea. Such remains are very rarely carried down and buried beneath modern lakes, and therefore were much less likely to be entombed beneath the deposits of the ocean.

Plants. In the following Table, M. Adolphe Brongniart compares the extinct flora of the Ancient World at four several periods with the vegetation which now covers the Earth. The general proportion is about 100 living plants to one fossil one.

	Première Période.	Deuxième Période.	Troisième Période.	Quatrième Période.	Epoque Actuelle.
1. Agames	4	5	18	13	7.000
2. Cryptogames cellulenses	—	—	—	2	1.500
3. Cryptogames vasculaires	222	8	31	6	1.700
4. Phanerogames gymnospermes	—	5	35	20	150
5. Phanerogames monocotyledones	16	5	3	25 ?	8.000
6. Phanerogames dicotyledones	—	—	--	100 ?	32.000
Indéterminées	22	—	—	—	—
	264	23	87	166	50.350
	$\underbrace{\qquad\qquad\qquad}_{540}$				

The immense disproportion between the numbers of fossil and living vegetables will probably not justify the inference that in ancient periods only a few species of plants covered the surface of the Earth. Only a small proportion of the vegetable tribes now growing upon the Earth are swept down into the sea, comparatively but a very trifling number would be carried there by even the most violent floods, and therefore the few hundred species of fossil plants are probably only a very small selection from the numbers that really covered the Earth. Nevertheless these few relics may be reasonably supposed to have been amongst the most abundant of the plants then in existence, and may be usefully employed in characterising the several periods of deposition.

Thus it appears that in the most ancient of the four periods defined by M. Brongniart, ending before the deposit of magnesian limestone, the most abundant fossil plants belong to the vascular cryptogamic class, including the natural families, ferns, equisetaceæ, lycopodiaceæ, &c., that in the third period, which includes the oolitic and cretaceous rocks, cycadeæ are especially numerous; and in the fourth or tertiary period the more complicated dicotyledonous plants appear, and thus gradually conduct us to the vegetation of the present day.

Zoophytes. Zoophytes, the first tribe of Animals to which we shall advert, are almost entirely marine. The flexible corallines, which contain the smallest portions of earthy ingredients, are but rarely seen fossil, but the stony corals

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and the hard echinodermata are exceedingly abundant in nearly all the secondary deposits

The following Table, from which Lamarck's ciliated polypi are excluded, will convey a good general notion of the relative proportions of recent and fossil zoophyta.

	Described British Species Recent.	Described British Species Fossil.	Recent Species described by Lamarck.
Polypi, nude	5	—	18
Celluliferous flexible	67	—	117
stony	21	26	61
Lamellated	3	30	134
Corticiferous	12	2	132
Carnose	47	25	194
	155	83	659

The proportion of British species is as 2 recent to 1 fossil.

	Recent.	Fossil.	by Lamarck.
Radiata Fistulida	11	—	41
Stellerida	19	5	76
Echinida	9	45	88
Crinoidea	1	27	3
	40	77	211

The proportion of British species is as 1 recent to 2 fossil.

It has often been thought, that the remarkable contrast in the proportions of the fossil and recent zoophytes of Britain might be explained by supposing that the ancient climate was hotter than at present; that, in fact, the former productions of our Northern Seas were of a tropical character; and this conjecture agrees with the deductions which may be drawn from similar comparisons in the other tribes of Animals. But the extreme rarity of flexible corallines is not confined to the strata of Britain, it is recognised over all Europe, and seems, at least in part, owing to their more perishable nature.

The contrast is equally striking among the radiaria; and it is especially worthy of remark, that the numerous group of crinoidea, so characteristic of the fossil races of a former World, belongs chiefly to the lower and more ancient members of the stratified rocks.

Passing over the remarkable Animals included in Lamarck's class tunicata, which appear to connect the zoophyta with the mollusca, and of which, being mostly perishable, no fossil species is yet recorded, we arrive at the class of conchifera, or bivalve molluscous Animals.

Conchifera.

Shells are the most numerous of all the organic treasures buried in the strata; a circumstance which might naturally have been expected from their durable constitution, their vast abundance in the present system of Nature, and their aquatic existence. When a lake is drained we find great quantities of shells in the silt which has filled its bed, but the remains of fishes and insects, and even of plants, are rarely met with.

British Conchifera.

	Described British Species Recent.	Described British Species Fossil.	Recent Species described by Lamarck.
Lamellibranchia.			
Plagymyona	186	396	800
Mesomyona	29	198	197
Brachiopoda.			
Equivalvia	—	4	—
Inequivalvia	5	159	15
	259	657	1012

The first thing which strikes us on comparing the catalogues of British recent and fossil bivalves, is the greater absolute number of the extinct species. The proportion is at present three to one, and when the strata shall have been as thoroughly explored as the shores, the number of our fossil conchifera will probably amount to a thousand, and be to the recent kinds as four to one.

On more minute comparison, we learn that the most remarkable discrepancy in the proportions is found in that singular tribe the brachiopoda, of which above 150 fossil species are already described, while the recent kinds do not exceed five. Perhaps these numbers on both sides will be changed by further discoveries. At least fifty species of spiriferæ, productæ, and terebratulæ remain to be described from the lower calcareous strata of England.

Gasteropoda.

We next arrive at the gasteropodous mollusca with simple univalve shells.

These we shall arrange in groups according to their places of residence.

	Described British Species Recent.	Described British Species Fossil.	Recent Species described by Lamarck.
Marine	210	398	1476
Estuary	—	21	22
Fresh water	31	23	50
Terrestrial	53	21 ?	274
	294	464	1822

Considerable difficulty is experienced in referring certain fossil shells to their respective recent analogues; and in consequence it is very probable that many of the species above, ranked as estuary and land shells, deserve a different arrangement. This is particularly the case with respect to the helices, helicinæ, and melaniæ.

According to the ordinary notion of their food, gasteropodous mollusca with shells may be ranked thus:

	British. Recent.	British. Fossil.	General. Recent.
Phytiphaga	233	263	786
Zoophaga	61	200	1036

Cephalopoda.

We are not aware that there are any fossil shells of the class of pteropodous mollusca, but the remains of the cephalopoda are inconceivably numerous, and far surpass the recent kinds in both variety and magnitude.

	British. Recent.	British. Fossil.
Cephalopoda	46	308

The fossil cephalopoda belong for the most part to genera not yet discovered in a living state.

The fossil species of vertebrated animals are comparatively very few, and some of them, especially fishes, not so perfectly characterised as to admit of much accuracy in their arrangement.

The following summary is chiefly taken from Mr. S. Woodward's Synoptical Table:

		British fossil.	
Fishes,	Fresh water. Marine	29	In various strata.
Reptiles,	Land. Aquatic	26	
Birds		6	In "diluvium" and alluvium.
Mammalia		1	In Stonesfield slate.
		28	In diluvium, alluvium, &c.

British fossil species.

Considered according to their situations of life, the British organic remains present the following results:

In the strata.

Terrestrial 113	Vegetables	90	and more.
	Shells	21 ?	Mostly very doubtful.
	Reptiles (Pterodactyli)	1	
	Mammalia	1	
Fresh water 56	Vegetables	5 or 6	
	Shells	40 ?	The genus Unio requires reconsideration.
	Fishes	11 ?	

Estuary 28	Shells	21 ?	
	Fishes		
	Reptiles (Crocodile, Emys. Trionyx).	7	
Marine 1139	Vegetables	3	or 4
	Zoophyta	83	
	Radiaria	77	
	Shells	909	
	Crustacea	30	
	Fishes	18	
	Reptiles	19	

In superficial alluvium, diluvium, &c. caves, &c.

Birds	6	species.
Mammalia	29	

European fossil species.

Such are the numerical relations resulting from a comparison of the extinct British species of Animals and plants on the one hand, with the recent organic Beings of Britain, and universal living races of the Globe on the other. These relations would doubtless have been considerably modified, had we found it possible to introduce accurately all the European species of fossils. But this task, owing to the still imperfect state of discovery on the subject, but far more to the unhappy confusion of synonyms, is at present hardly practicable. However, not wholly to neglect so important a datum, we shall take advantage of the information conveyed to us by Brongniart, Deshayes, Goldfuss, Dalman, and other writers, to compile a numerical statement of the most remarkable and ascertained European fossils, and to put them in comparison with a corresponding estimate of the existing species.

Remains of Animals.

	n the strata.	In superficial accumulations	Living estimated.
Mammalia	35	109	1100
Cetacea	8	—	—
Birds	few	few	5000
Reptiles	71	—	2100
Fishes	183	—	5500
Insects	74	—	100000
Crustacea	104	—	500
Annulosa	104	-	1000
Cephalopoda	788	—	100
Pteropoda	5	—	-50 ?
Gasteropoda, Zoophaga	107	—	1700
Phytiphaga	773	—	1400
Conchifera, Brachiopoda	379	—	40
Mesomyona	515	—	350
Plagymyona	1132	—	1400
Tunicata	—	—	—
Radiaria	278	—	1000
Polyparia	476	—	1000
	6027	109	122190
Plants	540	—	52000

Distribution of Organic Remains.

Number in different rocks.

The animal and vegetable fossils are very unequally distributed. For while some rocks are wholly filled with shells, others are absolutely devoid of them. Thus the forest marble and coarse upper beds of Bath oolite are composed of little else than shells, while the sandstones of a whole coal district may contain not one. This does not depend either on the absolute depth from the surface of the Earth, at which any rock may be found, nor yet upon its relative depth in the series of strata, but it is a circumstance established by experience, and of which some of the causes remain to be determined. The following Table exhibits the proportionate number of species of fossils in all the principal strata of the North of England, arranged according to their order of superposition.

	Thickness.	No. of fossil Species.	Ratio. Species.		Feet.
Chalk	505	43		to	12
Gault of Speeton / Kimmeridge clay	150	67 / 5	1	to	
Upper calc grit	60	5	1	to	12
Coralline oolite	60	125	2	to	1
Lower calc grit	80	40	1	to	2
Oxford clay	150	36	1	to	4
Kelloway rock	40	60	3	to	2
Cornbrash	5	37	7	to	1
Upper carboniferous series	200	30	1	to	6
Forest marble slate / Bath oolite	30	82	3	to	1
Lower carboniferous series	500	21	1	to	24
Lower oolite	60	91	3	to	2
Lias and marlstone	850	115	1	to	7
New red sandstone	?	none	——		
Magnesian limestone	215	30	1	to	7
Coal system	3000	100 ?	1	to	30
Mountain limestone	2500	200 ?	1	to	12
Old red sandstone	?	none	——		
Slate system	6000	20	1	to	300

Granitic rocks devoid of fossils.

It is necessary to remark, that the proportions derived from the preceding Table would apply only in a general way to the same strata in the South of England, for there the number of organic remains in the chalk is, at least, triple of that in the Table, the thickness remaining the same, while the mountain limestone is considerably less rich in fossils. Still less is such a Table to be viewed as a representative of the results of researches on the Continent, for there the red sandstone formation contains a very large suite of organic remains, both vegetable and animal, while neither have yet been found in this rock in England.

Fossil and recent species compared.

We shall now consider what are the *kinds of fossils* which are contained in these various strata: in other words, in what order of distribution the fossils are arranged in the Earth.

A great difference between the present system of Nature, and that of which the relics are preserved in the Earth, is obvious to any one who considers the relative proportions of the different classes of each. But the most decisive proof of the enormous changes which have happened in this respect is found by a minute comparison of the families, genera, and species. For except in the superficial and comparatively modern accumulations from fresh-water lakes, floods, or tides, and in the most recent of all the strata, scarcely one specimen of all the thousands of existing kinds of plants or Animals is found buried in the Earth.

The Earth contains the records of an ancient system of living Nature, which in its great outlines was calculated much like that which we now see in operation; but of which all the details were different. The ancient sea nourished Saurians, but they were not our crocodiles; fishes which are generally unlike the finny tribes of the existing era; innumerable shells planned on the same general principles, but executed to different patterns. The plants and the Animals of the ancient Continents performed the same relative functions as the vegetable and animal races of to-day, and formed part of a similar combination, but, as the circumstances of the Globe are now not the same as then, the forms and structures of its plants and its Animals are adapted to the difference.

Successive eras of fossil tribes.

But it must be obvious that to view the whole multitude of extinct Animals and vegetables as the products of one ancient era, to confound together all the various different strata which were successively the beds of the

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ancient seas, would be to destroy the meaning of all the monuments which Nature has preserved of the long periods and successive developements through which our Planet passed before the completion of its present beautiful arrangement. Each stratum was successively the bed of the ancient oceans or lakes, and the remains with which it is filled were the creatures then living in the waters or growing on the land. Each stratum, therefore, belongs to a particular period; it is the museum or repository in which Nature has preserved the plants and Animals of that period; and the Geologist, no longer confined to the mere comparison of recent and extinct species, finds in the Earth the proofs of many successive creations and abstractions of life, many systems of Nature; and by strict analogy and ample induction looks back through a long vista of revolutions, till the view is lost in the dimness and distance which hide the remote epoch, of which no evidence remains to show that the Earth was then inhabited by living creatures.

Terrestrial and marine fossils not usually abundant together.

The organic monuments of ancient Nature are either of marine, of fresh water, or of terrestrial origin. The corals, and by far the greater number of shells, are marine, certain strata are filled with lacustrine reliquiæ, and others with the spoils of the land.

There is in general the most remarkable and constant distinction and contrast between the rocks which are filled by marine remains, and those which enclose terrestrial productions. Calcareous strata generally are the most richly filled with the spoils of the sea, zoophytic, molluscous, and vertebrated Animals; but they rarely contain terrestrial plants. Sandstones and shales, on the other hand, are almost the exclusive repositories of terrestrial plants, but, unless they are calcareous, they more rarely contain marine exuviæ. The reason seems to be that the calcareous strata were deposited slowly and in tranquillity beneath the waters of the sea, and thus enveloped the dead and decaying animals of the ocean; while, on the other hand, the sandstones and shales were more rapidly aggregated, in water too agitated to favour the accumulation of marine reliquiæ. When we find in them few or no traces of land plants, we may perhaps presume that the currents to which they may owe their origin were marine, but when they are charged with ferns, equiseta, and other terrestrial plants, it seems evident that violent land-floods contributed to their accumulation.

Oceanic deposit of limestone.

The deposition of limestone by Chemical precipitation, would probably happen over a large portion of the bed of the sea, and be abundant in proportion to the depth of the water: hence the strata of limestone would thicken toward the centre of the oceanic basin. They would also be more condensed, and of more uniform texture, and perhaps of purer composition, in that direction; and since, from accurate observations of the habits of recent marine Animals, it appears that they do not multiply so much in the darkness of very deep waters as nearer the shore, we may conclude that fewer marine shells and corals, &c. should be found near the central points of the basins of strata.

How remarkably all these conditions agree in the limestones of the Alps, which appear to have been uplifted from very deep water, needs only to be mentioned. There, the rocks corresponding to our oolite, are vastly thicker, more dense, and incomparably poorer in shells, than the same strata toward the borders of the European basin. And if, in proceeding through France to the Alps, we stop to consider the Jura, we shall find its oolites, in respect of thickness and hardness, and quantity of shells of an intermediate character.

Littoral deposits of sandstone shale, &c.

On the other hand, sandstones and clays, being Mechanical deposits from agitated water, should of course be most abundant along the margins of the ancient sea, and at the mouths of ancient rivers, where the strongest movement of the waters happened. They are essentially littoral formations, and should be found thickest, and most numerous, and most varied in character, toward the borders of the basin, where the limestones are the thinnest. And as the forces of tides and currents, however powerful, are irregular and limited, the Mechanical aggregates which they occasion must be, and in general are, more confined and irregular than the wide Chemical deposits of the deep sea.

This supposition likewise agrees perfectly with what we observe in comparing the oolitic system of the Jura and the Alps with that of Northern France and England; for the clays and varied sandstones which diversify this system in the latter Countries, and separate it into many distinct groups, are scarcely to be traced in the Alps or the Jura.

Another case in point is furnished by the carboniferous limestone series of England. This limestone in the South of England is so little divided by Mechanical strata, that in the Mendip Hills, near Bristol, and around the Forest of Dean, it is commonly supposed to be one thick rock.

In the North of England it is much and evidently divided, and the number and thickness of the partings of shale and sandstone, and coal, increases continually Northwards, while the total thickness of the limestone beds grows less and less. At the same time the organic remains seem to become, if not more numerous, (a point as yet difficult to be determined,) certainly more varied in form.

The oolitic system of England presents us with another valuable illustration of the same doctrines.

The oolites of Somersetshire, Gloucestershire, and Lincolnshire form a long range of hills, and are only, and that not universally, divided by partings of clay and marly limestone. But as we advance into Yorkshire we find these spaces augment, and the widening intervals filled up by thick deposits of sandstone, shale, plants, and coal, which predominate so much in the section as almost to obliterate the separated, attenuated, and deteriorated limestones. These, however, are filled even more than usually with marine exuviæ.

The concretionary or oolitic structure is, perhaps, more decided and constant toward the borders of the strata. It becomes irregular, and at length fails in proportion as the limestone is mixed with earthy impurities. At the extreme Northern range of the degraded oolitic system in Sutherland this structure is nearly lost; it is irregular in the impure limestones of Yorkshire, becomes perfect in the homogeneous strata of Gloucestershire and Somersetshire, assumes more compactness in the Jura, and changes to dense limestone in the Alps.

This is exactly what, *à priori*, would be expected to happen. Amidst the turbulence and admixture of the littoral deposits, a process so similar to crystallization could happen but seldom and unequally, there would be a point at a certain distance from the shore at which the disturbance would prevent regular crystallization and yet would permit of concretion through the calcareous sediment, and still further the limestone would be more compact and subcrystalline.

Coarse conglomerates, for similar reasons, would be

most abundant toward the shores and more local than the finer sandstones and clays; which also would be most likely to contain the remains of plants, as these might be long suspended in the unsettled water, and be transported along with the finer matter.

The distinction here insisted on between *conchiferous and phytiferous rocks*, is so important, that we must, in speaking of the distribution of organic remains in the Earth, consider them apart; and while from the former we deduce the ancient condition of the sea at several epochs, the latter will furnish us with analogous data from which to reason on the state of the contemporaneous dry land.

We shall commence with the MARINE FOSSILS, and investigate the manner of their distribution under two general heads: 1st, their relation to the Chemical and Mineralogical composition of the strata; 2dly, to their relative antiquity.

Analogous fossils in similar rocks.

If the marine fossils are distributed in the rocks according to their Chemical nature, we shall find that similar rocks contain similar fossils. This is certainly the case with respect to the zoophytic animals, for these are almost confined to the calcareous strata. Corals, and various Animals of the class radiaria, abound in the transition limestone, carboniferous limestone, oolites, and chalk.

The remarkable brachiopodous bivalves, as spirifera, producta, pentamerus, terebratula, are also by far most abundant in the calcareous rocks. Gryphææ and smooth oysters are found in the argillaceous strata of the South of England, from the lias upwards to the chalk.

The organic remains of the different limestones of the oolitic formations have very remarkable general analogies. Thus the inferior oolite and the coralline oolite, the fuller's earth rock, and the cornbrash, hold very many closely analogous species. But it must be remembered that the distinctions of the oolitic system in England are in some degree local, and probably dependent on the littoral character of the deposits, and that in other parts all these subordinate strata coalesce together into one hardly divisible mass of oolitic limestone. The resemblance of fossils in these strata may, therefore, rather be the result of their nearly contemporaneous existence, than of the mere similarity of the Chemical composition of the rock.

These are the most remarkable instances of the association of certain organic forms with certain Chemical compounds; they are important data to support the opinion that, generally, fossil remains lie near the places where the Animals perished. But it is evident that these few analogies by no means establish a general law. On the contrary, when we proceed to consider in this point of view a large number of species, the resemblance between the organic contents of one limestone and those of another of considerably different age, is very slight and shadowy. And as no other strata than the limestones exhibit it in a striking degree, it is evident that some other cause than the Chemical composition of their repositories has regulated the inhumation of fossils.

Different fossils in strata of different age.

That cause is the subject of our next examination, the relative antiquity of the strata.

That a strict connection does really obtain between the age of a rock and the organic remains which it contains, is made evident by comparing a few well-ascertained facts.

The mountain limestone of the North of England contains, perhaps, 200 species of animal remains; the lias 115; and the chalk 43. Now of all the 358 species contained in the mountain limestone, lias, and chalk, respectively, there is *not one* which is found in two of these rocks. Neither of these strata contains a single fossil which is found in either of the others. Between the era of the formation of the mountain limestone, and that of the lias, the whole animal population of the sea had been entirely changed; and a similar complete renewal took place before the chalk was deposited. And in the Southern parts of England the chalk is covered by other more recent strata filled with shells and other marine Animals, entirely different from all those which lived and died before.

Identical fossils in rocks of the same age.

Further investigation has demonstrated, that conclusions thus drawn from local researches apply with considerable accuracy in other situations, even at great distances where the same strata occur. A catalogue of the corals, crinoidal remains, productæ, spiriferæ, terebratulæ, orthoceratites, and trilobites, of the mountain limestone in Yorkshire, may be employed for labelling the fossils collected from the same rock at Namur and Liege; the lias of Whitby contains many of the same ammonites, and the same Saurian skeletons as the contemporaneous beds at Lyme, and in Westphalia and Wirtemberg; and the remarkable echini and belemnites of the English chalk accompany that rock through France and Poland to the shores of the Baltic.

The same observations have been made on the other conchiferous strata of England. Each has been traced through the Island, and its organic treasures have been explored at every point, and in this manner satisfactory proof has been collected, that along its whole course the fossils which it contains are almost entirely the same. The researches of foreign Geologists have demonstrated the truth of this law for the greater portion of the European basin of strata. The figures and descriptions of the English fossils are referred to by the Geologists of France, Swisserland, and Germany, and no doubt remains that each extended stratum is the repository of the Animals inhabiting the sea at a certain period in the Earth's formation, exactly as the earthy bed of the present sea now envelopes the remains of its present corals, shells, echini, and fishes.

General principle of Smith.

The general principle, therefore, which regulates the distribution of organic remains in the Earth may be thus expressed. They are associated according to the periods at which they existed; and they are enclosed in the rocks which were at those times deposited by the water. And as in ancient times, much more than at present, the animal remains over considerable breadths of the bed of the Northern Sea were nearly identical, *strata of the same age contain generally the same fossils.*

Also because the inhabitants of the ocean were, in the course of time, completely changed, the old races having been extinguished, and new ones brought forward to occupy their places, *strata of different ages contain generally different fossils.*

These important propositions form the groundwork of the history of the stratified rocks, and must be ever present in the mind of the modern Geologist. The honour of their discovery belongs to Mr. William Smith, an engineer of eminence, who, being employed in 1790, and the following years, in surveying collieries, and planning and executing a canal in Somersetshire,

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established the English system of Geology upon the following propositions.

"That the strata are laid upon one another in a certain definite order of succession or superposition, may be traced in continuity on the surface of the Earth, and may be discriminated when of different ages, and identified when of the same age, by their imbedded organic contents."

Gradual changes in the races of organic being.

By comparing a sufficient number of fossils from all the several strata with analogous living tribes, we discover that those fossils which more nearly resemble the living kinds belong to the strata which were deposited at the least ancient period; as for example, the crag shells of Norfolk and Suffolk, the London-clay shells of Hampshire and Highgate, which are all more recent than the chalk.

In these situations we find the families, genera, and even species of shells so similar to recent kinds existing somewhere or other in the Ocean, that though they are often very different from the productions of our neighbouring seas, we not the less perceive that they belong to a system very like that now established.

On the other hand, those fossils which present the least resemblance to their successors in the modern system of Nature, belong to the older, and especially the oldest of all the conchiferous strata. It is in the transition and carboniferous limestones that the singular brachiópodous bivalves, producta, spirifera, pentamerus, the remarkable genus orthocera, the zigzag ammonites, the still unexplained tribes of trilobites, the beautiful crinoidea, chain corals, and favosites, compose a zoological suite, altogether unlike what now exists, a strange and antique order of beings adapted to the primeval deep.

If we estimate the relative periods which intervened between the deposition of any given rocks by the variety and thickness of marine strata which separate them, we shall find that in proportion to the distance of the strata from each other, in proportion to the difference of their ages, is the difference of their zoological contents. Thus the fossils of the mountain limestone are more different from those of the lias than from those of the magnesian limestone. The lias fossils are wholly different from those in the chalk, but partially similar to those in the Bath oolites.

M. Deshayes' results.

The principle that the difference of the forms of ancient organic life from those of existing nature is directly proportionate to the difference of the epochs of their existence, has been put to a severe and curious test by one of the best conchologists of France, M. Deshayes. Passing over the primary and secondary rocks, in which no plant or animal has yet been found identical with a living species, he analyzes the tertiary fossils according to their relative antiquity, and obtains the remarkable result, that the lowest and oldest of the tertiary strata contain three and a quarter per cent. of species identical with living types; that a second and less ancient group of these strata holds eighteen per cent. of such analogues; a third more recent group forty-nine per cent.; and the most recent of all these deposits contains little else than modern species. When we recollect that all these strata are of a date probably anterior to the creation of man and the present races of quadrupeds, the results of M. Deshayes' investigation must be considered as highly valuable data towards forming a just notion of the great antiquity of the stratified rocks, the long periods passed through in their production, and in the accompanying changes of organic life, the gradual nature of these changes, and the correspondence of the *General System* of Nature at all epochs, even amidst the greatest particular diversity.

Characteristic fossils.

Some fossils appear to have been in existence only during the deposit of one particular stratum, as for example, certain productæ, spiriferæ, trilobites, in the mountain limestone; axinus obscurus, in the magnesian limestone; ammonites Bucklandi, gryphæa incurva, in the lias; ammonites calloviensis in the Kelloway rock; hamites of many kinds in the Gault; ananchytes, spatangi, belemnites mucronatus, in the chalk; rostellaria macroptera in the London clay; fusus contrarius in the crag. These are said to be *characteristic fossils* of the strata, and, in general, very great importance is justly attached to their recognition; but no Geologist should permit himself to trust to them exclusively, for they are not *always and invariably* present, and he may be often called upon to fix the date of a rock by the help of other witnesses. Many fossils are found in more than one rock, and the number of these will probably be much increased by further inquiry. Thus in the South of England, plagiostoma giganteum occurs in the lias and inferior oolite, terebratula intermedia belongs to the great oolite and cornbrash, pecten lens is found in the cornbrash, Kelloway, and coralline oolite, astacus rostratus and spatangus ovalis range through the Kelloway rock, calcareous grit and coralline oolite of Yorkshire; and mya literata appears in nearly the whole range of conchiferous strata from the marlstone to the coralline oolite inclusive.

These facts entirely overthrow the notion favoured by some Geologists that each rock contains the relics of a distinct creation of animals. They prove, on the contrary, that the changes were not sudden but gradual; and suggest the hope that hereafter, when the laws of the *distribution and transference* of the *existing marine races* shall be better understood, and the history of the fossil species more complete, the phenomenon may be satisfactorily explained in accordance with the recognised laws of Nature, " constant in her ceaseless change."

Gradations of deposits and of fossils coincident.

It is generally observed that where the series of strata is complete, they are softened as it were one into another by an admixture or alternation of ingredients. Thus, for instance, in Somersetshire, the new red marl and lower lias clays are sometimes softened into one another; and in Yorkshire, the Kelloway rock, Oxford clay, lower calcareous grit, coralline oolite, upper calcareous grit, and Kimmeridge clay are so blended at their junctions as to render it difficult to draw any hard line of separation. In such cases it commonly happens that several fossils of the lower rock are continued into the next above, and thus the zoological change is as gradual as the mineralogical one. On the contrary, when two strata are separated by a hard and decided line, as, for instance, the coralline oolite and Kimmeridge clay near Oxford, we shall generally be justified in suspecting that the lower stratum is imperfect, in consequence of the removal of its upper beds before the next stratum covered it. In this case the zoological contrast between the two rocks is as decided as the mineralogical one, and keeping in view the Linnæan adage, *Natura non facit saltus*, we should be on the look out for some intermediate beds in other places. Such are described near Weymouth, by Sedgwick; and in Yorkshire, have been named the upper calcareous grit.

The chalk in England contrasts so entirely with the tertiary formations above, that we naturally expect to find in some other Country beds of intermediate character to connect them. These are found at Maestricht, where a sub-cretaceous, granular rock, intermediate in

composition between chalk and calcaire grossier, contains many fossils of the chalk, and several which strongly resemble those of the tertiary group.

The researches of Sedgwick and Murchison in the Eastern Alps, have brought to light the remarkable Gosau beds, which, by these Geologists, are thought to be of the same intermediate era.

Probably more complete researches on this point will make known a greater number of such intermediate strata, soften the contrasts between contiguous rocks, and fill up all the blanks in the harmonious system of gradually changing marine deposits, characterised by corresponding transformations of marine exuviæ.

Terrestrial animals and plants.

The remains of Terrestrial Animals embosomed in the Earth are very few, and those of plants bear so inconsiderable a proportion to the Flora of the present age of the World, as to give us much less information concerning the ancient state of the land, than the marine exuviæ afford of the former condition of the sea.

But as far as they go they confirm in the most satisfactory manner the conclusions drawn from the consideration of marine remains, of the succession of systems of organic nature. The plants which sometimes alternate with, and which overlie in immense variety and abundance the mountain limestone, are a group eminently distinguishable from those which belong to the oolitic coal beds. In the former deposit, lepidodendra, sigillariæ, stigmariæ; in the latter, cycadeæ and zamiæ; and the plants of the strata above the chalk are still of a different type.

It would thus appear that the same systems of calcareous rocks which contain the most remarkably different suites of zoological remains, likewise enclose in the alternating beds of sandstone and shale plants equally distinct.

As amongst the marine, so amongst the terrestrial remains, those most decidedly unlike the modern productions of Nature belong to the most ancient deposits. In the intermediate portion of strata the discrepance diminishes, and in the most recent rocks, the plants strongly assimilate to the genera and even species which now cover the surface.

We might here examine the conditions of the land and sea as to climate during the several epochs of organic existence, a subject of the greatest curiosity and interest, and for which an immense mass of materials is already collected; but this investigation requires the statement of details which cannot be here with propriety introduced. We must, therefore, postpone the discussion till we come to treat of the strata and their contents in the order of their successive deposition.

We shall then also enter into the history of the fresh-water formations which locally diversify the great mass of marine deposits, and contribute to elucidate the character of the ancient land and streams.

CHAPTER II.

DESCRIPTION OF THE SERIES OF AQUEOUS DEPOSITS WITH THEIR IMBEDDED ORGANIC REMAINS.

Series of Aqueous Deposits.

General basis of Plutonic rocks.

Having now stated general principles, useful alike to the Geologist who investigates in the field, and to the student who reads in his closet, we proceed to describe the successive systems of aqueous deposits, beginning with the lowest of all, *viz.* those which rest upon granite and other crystallized and unstratified rocks. That there is such a basis of crystallized rocks beneath all the strata, in all Countries, cutting off and limiting our observations, and hiding whatever wonders are concealed below, is now universally admitted. The subjacent position of granite is so fully established by observation, that even when portions of it are clearly seen to be laid upon stratified rocks, no doubt is entertained of its having been in every case ejected from its true source below all the strata. But the same observations, which so clearly establish this important law, as certainly overthrow the dogma, once held incontrovertible, that granite is always the oldest of known rocks. They prove to a certainty that granite is of all ages, or, more properly speaking, that its production has really no relation of age to the deposition of any particular set of aqueous strata; but that it has been produced by agencies entirely independent of them, and only locally, and in one sense accidentally, brought into juxta-position with them. This interesting discovery, from which we learn that the production of granite below the stratified rocks has been continued, perhaps without intermission, during the whole period of the accumulation of the strata, has greatly changed and improved our conceptions of the whole system of Geology, and is probably destined to clear still more the horizon of this Science. But we must be careful not to be allured by this new light too far from those inferences concerning the age of granite which it so properly qualifies. It does not follow, because some granite is more recent than chalk, that therefore all granite is more recent than gneiss and mica slate. It does not follow, because when in contact with granite veins gneiss may sometimes assume perhaps more than even its usual granitoid aspect, that therefore granite is merely fused gneiss, that gneiss and slate are incipient granite, and that common sandstone may in time become gneiss.

But it does follow, as a matter of high probability, independent of further observation, that because granite has been formed at several periods during the deposition of strata, by agencies excited far beneath and independent of them; and because, in some instances fragments, and universally the disintegrated ingredients of granite, lie in the oldest strata, that the production of this rock was in progress before any of the strata were deposited; whether those strata now rest upon that old granite or have been forced by subsequent convulsions into contact with newer portions of the same kind of rock.

Whatever theory on the original formation of granite we choose to adopt, it must be allowed that the igneous action to which it owes its birth preceded the aqueous, which accumulated the lowest strata now observable.

Primary strata

This being admitted, two points of inquiry suggest themselves with respect to the age of the strata which have been called primary. First, are those strata really

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the altered deposits of one long period of aqueous action prior to all the secondary and tertiary strata, or have many repetitions of igneous action *primarized*, to use Mr. Conybeare's remarkable expression, strata of all ages, secondary and tertiary, which happened to be the lowest at the points of action? Secondly, may we believe, as the title of primary seems to imply, that these are the oldest of all the strata, the first that were laid by water upon the consolidated igneous crust of the Globe? That these questions should be put at all will probably appear very surprising to those who have drawn all their notions on the subject from books of some date, without attending to the rapid progress of geological opinions.

not to be known only by mineral characters,

On the first question we may remark, that it must be allowed that subterranean heat, operating chiefly by the ejection of melted Plutonic rocks, has transformed to a certain degree and limited extent, strata of all ages which were exposed to this action, and thus made the lias shale of Savoy, for example, approximate to the character of clay slate. In such cases, there can be no objection, we conceive, on the part of any Geologist to apply the same term to this *change* of the rock, which we may think fit to employ when treating of the analogous *change* presumed upon very good grounds to have affected in more ancient times the strata called primary. We may, therefore, adopt at once Mr. Lyell's term of *metamorphic*, and designate by it all those parts of certain aqueous strata which have been transformed in structure or appearance by subterranean heat applied since their deposition. All strata then may become metamorphic under given conditions, and may assume, locally, some of those appearances which belong, perhaps universally, to the primary strata; but are we, therefore, to deny the antiquity of these latter? or to group all such metamorphic strata together as of indefinite age, and merely characterised by proximity to igneous rocks? Surely nothing could be more in contradiction with the principle of classification of strata, the relative antiquity of their deposition. We cannot, therefore, agree to the term *hypogene* of Mr. Lyell as applied both to granite and the strata usually called primary. When applied to granite it is synonymous with, and may perhaps be preferred to Plutonic; when applied to stratified rocks its meaning is better conveyed by the term metamorphic, which we shall apply to those portions of all strata, without regard to their age, which are in the altered condition implied.

but by their position.

The true conclusion on the subject of the first inquiry then appears to be, that we are not to assume strata to be of the primary age merely because they appear to have undergone certain changes, analogous to those which gneiss or clay slate have sustained; but we must determine their age by the very same methods as we use in any other case of stratified rocks, *viz.* by examination of their position relatively to other strata, their organic remains, and their original mineral composition and structure. Examined in this way, there can be no doubt, we conceive, that the use of the term primary as applied to the gneiss, mica slate, and clay slate systems generally, defining them as a certain mass of strata anterior to the secondary and tertiary rocks, is perfectly correct, because in all Countries where these rocks occur together, the inferiority of their position is well proved; and they have those general analogies of original composition, and those relations to organic remains, which would be satisfactory evidence in every other case. Those who reject the term primary, and yet retain the use of secondary and tertiary, have constructed a series wanting its first term.

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Are primary strata the earliest deposits from water?

The answer to the second inquiry cannot, perhaps, in the present state of knowledge on the subject, be given with the confidence of assured impartiality. It certainly does not follow that because gneiss, for example, is generally allowed to be the lowest of the stratified groups which we can trace, that there may not be other strata of a totally different nature below it, partially or wholly concealed by Plutonic rocks, still less is it evident that such strata may not have existed, and been subsequently absorbed into the general mass of igneous rocks below. Geologists of eminence appear to think that granite itself is a derivative igneous, from an earlier stratified rock; and that as gneiss is certainly in some respects to be compared to partially fused sandsone, so it may be supposed that while, above, the mass of strata was augmented by additions from water, it was diminished, below, by the transforming action of heat.

Strange as this notion may appear we certainly are not at present in possession of facts sufficient to wholly disprove it. But neither are there any facts to raise it above the rank of a general speculation grounded on particular and local alterations of stratified rocks. It cannot, therefore, be admitted for want of sufficient evidence, and, perhaps, the following considerations will justify us in rejecting it. Many of the primary strata undoubtedly are derived from the disintegration of preexistent granitic rocks. The character of the organic remains in these strata is in general so remarkably contrasted with those which at present exist, that, joined to the diminution and final extinction of their numbers as we descend in the series, and the almost perfect identity of their characters over immense geographical areas, we seem really to behold in them the first terms of organization, the earliest records of the establishment of life upon the consolidated crust which overspread the fused matter within the Globe.

Conclusions admitted.

However, without plunging further into premature speculations of this nature, we shall content ourselves with the admitted conclusions.

1. That there is a sequence of age to be traced through all the stratified rocks, which may, therefore, be very justly grouped in any suitable number of successive divisions, as primary, secondary, and tertiary, and that these terms, if convenient, are not improper.

2. That the series of stratified deposits, whether we know their first terms or not, were laid upon a general basis or floor of Plutonic rocks.

3. That the term primitive, whether applied to igneous or to aqueous deposits, must be abandoned, as affirming what is not, and perhaps cannot be proved.

4. The alteration of strata by general igneous agency, or by the local contact of melted rocks, being an effect wholly independent, both as to cause and period, of the deposition of strata, must be treated in connection with the other effects of subterranean heat.

Governed by these considerations, the succeeding part of the Treatise will form two clearly marked divisions: 1st, the description of the products and operations of water through all geological periods to the present time; and 2d, a similar account of the products and operations of heat.

Exceptions to this rule will occasionally occur where it is necessary to notice the changes produced by igne-

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ous agency in the condition of the bed of the sea, and other circumstances which influenced the character and extent of the aqueous deposits.

In the following description of strata, we shall retain the general titles of Primary, Secondary, and Tertiary Strata, and divide them into several SYSTEMS according to certain properties, or in agreement with their elective associations. The reasons which have determined the mode of arrangement in each case will appear in the history of the several systems.

PRIMARY STRATA.

System of Gneiss and Mica Schist.

These strata, derived probably from decomposed granitic rocks, with several subordinate and associated strata, all devoid of organic remains, constitute, according to the concurring testimony of geological observers, the lowest group of the whole series of Neptunian deposits. From the effects of heat upon these rocks, their natural analogy to granite is sometimes so much heightened, as to cause some uncertainty in distinguishing between them. The rocks of this whole series might without impropriety be termed *granitoid strata.* They are usually called primary, sometimes primitive strata. We use the former term in the same sense nearly as that in which M. Omalius d'Halloy employs the title primordial, and intend that it shall be understood to include the following system.

System of Argillaceous Slate.

In this argillaceous series, which includes the whole mass of the slate rocks of England and Wales, lie the most ancient organic remains yet discovered. The calcareous slates of Caermarthenshire, the black limestones of Norway, the shelly limestones of Shropshire, Dudley, and the Eyfel, belong to this division, which is generally known by the term of transition strata; a title which is found convenient, but considered by many modern writers too theoretical to be often employed with propriety. We shall chiefly employ it to designate the limestones of this period.

SECONDARY STRATA

as they occur in Europe. It is probable that other modes of arrangement will be found necessary for other regions.

System of Carboniferous Strata.

Containing a very large series of sandstones, limestones, shales, coal, and ironstone, with abundance of marine exuviæ in the calcareous portions, and a profusion of terrestrial plants in connection with the coal. The lower part of the system consists principally of red sandstone, the middle of limestone, the upper of coal shales and sandstones. The limestone has been long known in England by the name of mountain limestone.

System of Saliferous Strata.

We have chosen this title, because rock salt is exclusively found in these strata in England, and is especially abundant therein throughout Europe. This remarkable mineral is, however, found, though not in Britain, in several other parts of the series of secondary strata.

Red and white sandstones with red, white, and blue clays, gypsum and rock salt, constitute the mass of this system; and locally enclose two principal calcareous rocks, the lower one usually charged with carbonate of magnesia, the upper one a shelly limestone not known to occur in England.

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System of Oolitic Strata.

Consisting in England of several distinct groups of calcareous rocks, alternating with clays and sandstones which are often calcareous, the whole remarkably rich in marine exuviæ, with local interpolations of terrestrial plants and coal deposits, and one estuary formation.

The lowest limestone group is usually argillaceous, the others are mostly nearly pure carbonate of lime, and very generally oolitic. On the Continent many of the minute distinctions of these rocks disappear.

System of Cretaceous Strata.

Chalk with argillaceous marls and layers of nodular flint, form the most remarkable part of this system, and it graduates below to green, grey, and ferruginous sands, with layers of nodular schist, rich in organic remains.

TERTIARY STRATA.

These form, properly speaking, only one great and various system of sands, clays, and coarse limestones, stored with great numbers of marine exuviæ always very analogous to, and in the most recent group identical with existing species, locally interstratified with freshwater deposits of marls, limestones, and gypsum.

Above all these systems of strata lies a variety of tumultuary deposits apparently produced by violent action of moving water during and subsequent to the elevation of the tertiary strata, and enclosing in abundance the remains of extinct quadrupeds. These are termed *Diluvial Deposits.*

Lastly, we have the products of modern rivers, lakes, and tides, or generally, the deposits, whether chemical or mechanical, which have been effected by water acting *as* it now acts, and *where* it has acted, since the last great revolutions by which the relative level of land and sea has been changed. These are called *Alluvial Deposits.*

Range of the Primary Strata.

Study of mountains.

At all periods in the history of Geology, persons of enlarged views have passed over the limited areas of particular Islands and Kingdoms and have sought to connect the results of their local inquiries with those drawn from similar researches elsewhere. In this point of view the long chains and insulated groups of mountains become of the highest interest. These lofty peaks on which the snow rests for ever, whose rocks contain no vestiges of life, may be imagined to have stood up in ancient times above the level of the waters, dividing the primeval deep into seas very different from those which now branch off from the Ocean. And though this supposition is probably inaccurate, though modern researches render it extremely credible, that in fact the mountain ranges, far from limiting the ancient sea, and altering the nature of its deposits, were really raised out of its depths at periods comparatively recent, this does not diminish their geological importance. For if by means of this uplifting we are made acquainted with some of the materials which would otherwise have been concealed from the eye of Philosophy, these mountain ranges must be studied as the basis of the whole system of Geology.

They form, so to speak, the skeleton of the Earth, and are the marking features of its topography; their insulated groups characterise Kingdoms, their long connected chains divide the races of mankind, and define the geographical limits of the distribution of land animals. To the Geologist they have become still more interesting in consequence of a remarkable general law of their physical structure. For in all climates of the Earth, under every conceivable variation of external circumstances, the principal ranges of mountains are everywhere composed of similar rocks, and those originally the lowest, and in part at least the oldest, with which we are acquainted. By what violence from below they have been uplifted to their present heights, so as to break through and rise from beneath the strata which were superimposed upon them in succession, is a capital question in Geology.

These rocks are the primary strata of gneiss, mica schist, slate, and their many associated strata, the deposits of water, resting upon and often pierced by granite and other crystallized compounds from fusion. An outline of the mountain groups and chains which diversify the face of our Planet, seems, therefore, the best foundation for a systematic view of the strata which rest against these rocky barriers.

Relations of mountain ranges and groups.

It has long been the fashion to attempt to establish certain geometrical relations among the chains of mountains, to refer them to particular parallels and predominant directions, but this labour, unconnected with Geological researches, seems to have been very fruitless. Perhaps it would be more correct to say the essence of the geographical relations amongst mountains is irregularity. For though we speak of long-continued chains and belts of mountains, it is very certain, in fact, that to be assembled in groups is the real character of mountain association, and that the chains and belts are nothing but approximated groups. A Geological Map is in this respect a most valuable instructor; from it we see that, instead of the plains being insulated among the mountains, instead of the upper strata appearing in small contracted patches like oases in a desert, they spread wide, and flow round the bases of the mountains, as the Ocean encircles the islands and continents. Among the few general remarks on this subject we may observe, that the most insulated and many of the loftiest eminences on the surface of the Earth are the volcanic summits; the most connected ranges of uniformly high ground are formed by the secondary limestones. Finally, that the general outline of Countries is much influenced by the direction of their interior mountains.

European basin.

The Scandinavian chain, commencing at the North Cape, runs parallel to the coast of Norway, and gives off branches to the East which pass round the Gulf of Bothnia. The line of the Scandinavian chain may be imagined to cross the sea to Zetland, and from thence to proceed by the Hebridian Isles and the North-Western half of Scotland to Ireland, where it is much broken into separate groups in the North, South-East, and South-West of the island. The Isle of Man, the South-Western part of Scotland, the Cumbrian group, the broken mountains of Wales, and those of Devon and Cornwall, are so many separate protuberances of the exterior rocks of the Earth, which, with Bretagne and the North of Spain, compose the interrupted Western border of Europe.

The Pyrenees, ranging to the East, may be considered as carrying on, the primary range toward the Alps, which hold so long a course from the shores of the Mediterranean in a winding direction to the Danube, and seem to prolong themselves in the inferior ridges of the Carpathians toward the Black Sea and the Caucasus. If, now, we consider Caucasus as continuing the Alpine line round the Caspian Sea to the lofty Paropamisan and Gaur mountains, and from thence turn Northward along the summit of drainage including the Sea of Azof, we come to the Uralian chain, which leads us to Nova Zembla, and thus we find nearly all Europe, and a considerable tract in Asia, enclosed within this irregular circle of primary mountain groups; and it may often hereafter be convenient to speak of this space as the European Basin. It is within this region that the greatest variety of stratification has been observed.

Within this area are the primary elevations of the centre of France, the Ardennes, the Vosges, the Black Forest, the Thuringerwald, the Hartz, and the Bohemian Circle; South of it are the Sierras of the Spanish peninsula, Corsica, Sardinia, the Apennines, the Dalmatian ridges, and the mountains of Greece and Mount Hæmus.

The mountains of Africa are long, unconnected ranges. Atlas borders the Northern shore, a range parallel to the Equator determines the course of the Niger, and, perhaps, the prolongation of it defines the drainage of the Nile. The high land about the Cape runs in various directions.

Asiatic basins.

Another basin of about equal extent, but more perfectly defined in its boundaries, and more uniform in its interior composition, is that great Siberian tract which lies to the East of the Uralian, and to the North of the Altaian, Yablonoy, Stanovoy, and Kamschatdale mountains. The vast Empire of China and Tartary lying to the South of the Siberian basin, and to the North of the Indian Empires, may be considered as a third great but divided basin between the Himala and Altaian heights.

The peninsular Indian regions, with their islands stretching toward New Holland, Persia, Arabia, derive their features from considerable primary mountains directed more parallel to the circles of longitude; the Southern part of Africa is similarly defined by the long ridges of mountains which run from Cape Guardafui in the East, and above the sources of the Congo on the West, to converge about the Cape of Good Hope; while the greatest breadth of this peninsulated continent, from Cape Verde to Cape Guardafui, is coincident with the high mountains of Kong, Donga, and Southern Abyssinia, and the North-Western projection is caused by the elevated Atlas.

Principal line of mountains.

The interrupted system of primary mountains which extends from the Pyrenees to Behring's Straits may be supposed to continue in the long and magnificent Cordillera parallel to the whole Western coasts of America, while the North-Eastern shore is parallel to the Alleghany and its Northern connections, and between these and the Western Cordillera, the vast basin of the Mississippi pours its waters into the Gulf of Mexico. The Eastern projections of the coast of South America, which is in a certain degree correspondent to that of Africa, are owing to lateral extensions from the great Western Cordillera.

Though the above enumeration and classification of mountains be extremely imperfect and subject to many objections, it answers the purpose intended, which was to show that the leading features of our continents, their geographical extent and connections, are dependent on

the lines of mountainous land, and as these are constituted of the lowest and oldest stratified resting on granitic rocks, it generally happens, as Mitchell foresaw, that in every Country the secondary strata are arranged with reference to the lines of mountains.

Elie de Beaumont's Theory.

An entirely new kind of interest has lately been given to this subject in consequence of the researches of an eminent foreign Geologist. Elie de Beaumont, from considerations of some observed accordances between the direction of mountain chains and the geological era of their uplifting, has advanced the hypothesis that these two circumstances are always mutually dependent; and, in consequence, supposes that all ranges of mountains which were uplifted at the same period are parallel to one and the same great circle on the sphere. This is not the place to examine this curious question as fully as it deserves, and we shall, therefore, only mention some of the cases in which this ingenious Geologist supposes that the truth of his doctrine may be recognised.

If a great circle be conceived to pass round the Earth through Natchez and the mouth of the Persian Gulf, and the directions of mountain chains be compared with it, it will appear that the Pyrenees, part of the Apennines, the Dalmatian and Croatian ranges, and part of the Carpathians, are parallel to it. Now in accordance with some researches of Geologists, M. de Beaumont supposes that all these mountain-chains were thrown up at the same geological epoch. Nearly parallel to the same circle are the Alleghanies of North America, the Gauts of India, and the Paropamisan heights; but further information must be acquired before we can be asked to admit that these mountains may have been thrown up at the same epoch.

Another circle may be traced on the sphere parallel to the Alps, from the Valais to Styria, and to this system we may refer the Atlas, the Caucasus, the Balkan, the Himala, &c.; and, according to the hypothesis of M. de Beaumont, these must have been all raised at so late a period as since the deposit of the tertiary strata. This subject will again attract our attention.

Gneiss and Mica Schist System.

Principal rocks of the gneiss and mica schist system.

This consists principally of the two following rocks:

Gneiss, a rock composed of the same mineral ingredients as granite, but laminated and stratified;

Mica schist, composed generally of quartz and mica, in alternate layers.

With these are associated, and often intermixed,

Quartz rock, generally appearing like a semi-crystalline or imperfectly granular mass of quartz, variously modified by small interspersed quantities of mica, felspar, &c., sometimes more compact, and resembling the quartz of veins, in other examples mixed with clay slate.

Crystallized limestone mostly granular.

Serpentine, a magnesian rock generally distinguishable by its softness, smoothness, and bright mottled colours.

Steatite, a still softer and smoother rock than serpentine, generally of whiter colour.

Potstone, a soft, often grey or greenish magnesian rock.

Hornblende schist, a laminated rock of hornblende, variously modified by felspar, mica, and chlorite, generally in alternate laminæ.

Chlorite schist, a rock almost precisely similar to mica schist, with the exception of the difference between chlorite and mica. It is subject to the same contortions as mica schist, and passes like it by insensible gradations to gneiss and clay slate.

Talc schist, mentioned by M'Culloch, is another of the fissile rocks which differ from mica schist only by the substitution of one mineral for another. It is rare.

With respect to the order in which they succeed one another, nothing very definite can be advanced. The greater number of observations concur in assigning to gneiss the lowest place in the system, a conclusion supported by its evident analogy to granite, and in the same general way we may, perhaps, place quartz rock and chlorite schist in the upper part of this system, and next to the clay slate, with which, indeed, they are often associated. Limestone and serpentine are so irregular and peculiar in their occurrence, that though, perhaps, their era is more definite than that of any other of these rocks, they can scarcely be employed to mark a geological date. In some district or other nearly all these ancient rocks alternate with one another so variously and unequally, that what would be called the oldest rock in one region may be the youngest in another, and, therefore, it is no wonder if the attempts which have been made to divide the gneiss and mica schist system into several distinct formations, have wholly failed. It is not till zoological evidence is brought to bear on the subject that we are able to demonstrate completely the relative age of strata, by distinguishing different deposits and different ages of the same kind of rock.

Gneiss. Its origin.

That the materials of the mechanically aggregated gneiss rocks, of the whole series of strata, in fact, except the calcareous rocks, are derived from the disintegration of more ancient granite and other crystallized compounds, is an opinion which is strongly impressed upon every Geologist while examining the composition of gneiss.

The ingredients of gneiss and granite are the same, quartz, felspar, and mica; they are mixed with the like accidents and permutations, and occasional admixture of other minerals, and are subject in both to the same extreme variation of size. But these rocks differ in the most essential point of view under which they can be compared, *viz.* the mode of arrangement among their constituent masses. The ingredients of granite are so connected together by contemporaneous, or nearly contemporaneous crystallization, that one substance penetrates and is united into another, and we are compelled to conclude that they were accumulated together not in distinct pieces ready formed, but that they actually never had a separate existence as solids until their different properties were developed by crystallization from a fused mass.

On the contrary, gneiss well characterised shows evidently, by some degree of wearing of the edges and angles of the quartz and felspar, and much more decidedly by the laminar arrangement of the mica, and consequent minute stratification of the rock, that its materials, ready made and crystallized, were brought together and arranged by some mechanical agent, principally influenced by gravitation, in fact by water. Could any doubt remain on this subject after a sufficient examination of gneiss strata, in all their gradations from a rock resembling granite to a fine grained fissile mass, hardly distinguishable from clay slate, it would be at once removed by comparing them with a suite of sandstones, many of which, like gneiss, are composed of granitic debris and strongly allied to it in structure, but most evidently aggregated by water.

In a great majority of instances, gneiss rocks immediately follow granite; being then composed of the materials of that rock which had suffered the least degree

of waste and abrasion, it is no wonder that on several occasions it should strongly resemble its parent. And if we allow, what may probably be true, that the heat of the granitic nucleus was then sufficient in some places materially to affect the consolidation of the strata on the bed of the sea, we shall perceive another cause why the most ancient mechanical strata approach in character to the Plutonic rocks.

Though the disintegrated *materials* of granite compose almost universally the substance of gneiss, *fragments* of granite are most rarely discovered in it. This circumstance, combined with its numerous laminæ and crystalline aspect, seems to indicate that the aggregation of gneiss happened without any great degree of turbulence or lateral motion in the water. It may, perhaps, lead us to suppose that in those early periods the fluctuating temperature of the bed of the sea contributed sometimes to accelerate the aqueous decomposition of the granite, and afterwards at intervals to harden its stratified materials into gneiss.

Stratification of gneiss.

Gneiss beds are of extremely various thickness, and the laminæ of which they consist are subject to such extraordinary curvatures, that it is often very difficult to trace them.

Where other rocks alternate with gneiss, as hornblende slate or mica slate, the stratification is rendered very evident, but otherwise the beds are less regular, and are often discontinuous, as in micaceous sandstones and in argillaceous slates.

The contortions of the laminæ of gneiss are observed to be most numerous and surprising, where, as frequently happens, veins of granite, quartz, or felspar divide this rock. These veins cross the laminæ at various angles, and generally cause some peculiar twists along their sides; they not unfrequently insinuate themselves between the laminæ, and in this case, when thick and extensive, may be mistaken for alternating strata. It is probable that many cases of supposed alternation between gneiss and granite may be thus explained, and that in other cases the rock called granite may be really a coarsely granular gneiss, whose particles have been very little moved by water, or unusually affected by subsequent application of heat.

Minerals.

Gneiss being one of the most extensive stratified rocks is a rich repository of minerals, both in the New and the Old World. Garnets frequently, zircon, beryl, disthene, epidote, tourmaline, rutile, oxide of tin, oxide of iron, sulphuret of molybdena, more rarely, are disseminated in its laminæ. The veins of quartz, calcareous spar, carbonate of iron, and sulphate of barytes, which divide it, contain the sulphurets of lead, copper, and zinc, native silver, tin, &c. (*Brazil*, Humboldt,) and many other minerals occur in the calcareous strata which alternate with or are enveloped by the strata of gneiss.

Rocks associated with gneiss.

Gneiss alternates with granite in the Reisengebirge and in Quito, and in some cases graduates into the character of granite, as on the Southern declivity of the Titlis and Jungfrau; (Humboldt;) more frequently it exchanges beds with mica schist, hornblende schist, and granular limestone and clay slate. These rocks are sometimes in such small quantity as merely to mark lines of division in the mass of gneiss, but at other times they swell out to great thickness. The limestone beds in particular are remarkably local and irregular in their occurrence, and instead of extending, like the more recent calcareous strata, through large tracts of country, appear in the form of large lenticular masses, enveloped on every side by the predominant rocks of gneiss. The term *subordinate*, on a great scale, is not improperly applied to these lenticular rocks, though in local Geology, their occasional great extent and comparative regularity may entitle them to be classed under an independent title. Thus Charpentier arranges the granular limestone of the Pyrenees.

By the substitution of hornblende for mica, gneiss gradually changes to hornblende schist; the loss of its felspar approximates it to mica schist, the diminution of its mica produces the resemblance of quartz rock. A finely granular state, with more evidence than usually appears of watery friction among the particles, almost transforms gneiss to sandstone; a more minute admixture of its ingredients, with a predominance of chlorite, gives it the aspect of argillaceous slate. In all these cases great caution is required, and its geological relations should always be consulted before deciding on the name of this Protean rock. These gradations happen most frequently at the junctions and alternations of the several rocks.

Mica schist. Its origin.

Mica schist, like gneiss, appears to have derived its ingredients from the destruction of granitic rocks; but it generally contains but little felspar. May we conjecture that this mineral, which is easily acted on by ordinary agents, was itself decomposed during the disintegration of the granite, and mostly dissolved, leaving the quartz and the mica to be arranged by the water in the alternate layers which render this rock so remarkable?

The lamination of this rock is subject to much unevenness, in consequence of the irregular size and arrangement of the pieces of quartz, and the undulations thus occasioned on the micaceous surfaces, are often further modified by interspersed garnets. Besides this minute inequality, the laminæ of mica slate are liable to the same contortions and curvatures as those of gneiss; the same difficulty often occurs in tracing its beds, similar and very numerous veins of quartz traverse and mingle with its layers, and when in contact with granite it is locally penetrated by similar granite veins.

Minerals.

Various minerals are similarly disseminated through it, as garnet, emerald, beryl, disthene, tourmaline, felspar, epidote, hornblende, columbium, molybdena, rutile, oxide of tin, wolfram, oxide of iron, grey cobalt, native gold. Its metallic veins are of the same nature as those in gneiss; it alternates in the same way with quartz rock and the other slates, and encloses similar deposits of limestones. It seems, therefore, almost superfluous to say, that the line of rigid distinction between the mica schist and gneiss can only be drawn in the closet. Yet, in fact, on a great scale the two rocks retain their typical characters over large tracts of country, and must be considered apart.

Quartz rock.

Quartz rock, in the greater number of instances, seems a more recent deposit than mica schist and gneiss, though indeed, by an easy change of its composition, it becomes nearly identical with them. This circumstance, combined with the internal evidence of texture, seems to decide the question of the origin of quartz rock, and to prove that, however altered by subsequent igneous action, it is originally a Neptunian and mechanical deposit. The degree of compactness which it exhibits varies through a large range, in some cases approaching the loose granular character of sandstone, in others the density of the quartz of veins. In this latter case it seems that the mass is composed of fragments so firmly

united as to suggest the idea of their having been fused together since their deposition from water. Perhaps, also, in some cases, what has been considered as quartz rock may be really an expanded or overlying vein.

Minerals.

In South America this rock is the repository of many rich ores and metals. Native gold is found in Brazil in a stratified rock of quartz, and micaceous iron ore, which is suspected by M. Eschwege to be the original repository of diamonds, and appears to be intimately related to quartz rock. The flexible quartz of the same country is a granular rock with drusy cavities containing topaz and amethyst. (Brongniart.)

Crystalline limestone. Its origin.

Crystalline limestone is in general observed to be stratified, frequently to alternate with gneiss and mica schist, and is therefore a Neptunian deposit. Its frequent high state of granular or saccharoid crystallization may perhaps be due to changes operated since its deposition, and partly occasioned by the action of subterranean heat, of course more sensible in the lower than in the upper calcareous deposits.

It is difficult to imagine that such a rock could be formed by crystallization from water, often in laminæ exceedingly thin and regular, and alternating with evidently mechanical deposits. That the calcareous matter of many rocks, at first precipitated in sediment, has been since arranged in crystalline and concretionary masses, is certain. Thus the oolitic structure, thus the crystalline cement of the Lincolnshire oolites, has been occasioned. These effects, it is now known from artificial trials and from observations in Nature, are more decisive when heat and pressure operate upon the particles. By this combination, the earthy sediment of chalk is condensed into crystalline limestone.

The deposits of crystalline limestone, whether distinctly stratified or not, are in general detached and limited, and so entirely enveloped in the strata of gneiss and mica slate, as to compose but a subordinate member of those extended formations. This fact appears to indicate that in the earliest periods of Neptunian operations, the precipitation of calcareous matter was occasioned by agencies of a more local and limited nature than those which produced the broad strata of lias, oolite, and chalk.

May we imagine that the accumulation of these nucular or lenticular masses was determined by local developements of subterranean heat, which directly, by change of temperature, or by intermediate chemical agencies, might render the calcareous matter insoluble? However we may seek to explain it, the fact is undoubted, that during the aggregation of the gneiss and mica slate systems, a large quantity of calcareous sediment was deposited, not in one uniformly extended stratum, but at scattered points, and in unequal quantity. And this irregularity of deposition continues to be observed in an inferior degree in the limestones of the clay slate system, which are often lenticular, but above this point, when the influence of the internal heat must be supposed less intense and more equally diffused, the calcareous strata become at once more abundant, more regular, and more uniformly extensive.

Minerals.

Though primary limestone be, in fact, a simple rock, its aspect admits of many variations from the unequal admixture of other mineral substances. Of these the most frequent are mica, talc, and steatite, the latter of which often communicates a green or mottled colour to the whole rock. Crystals of augite, (Tiree,) garnets, and felspar, (Col. de Bonhomme,) occur in it in some places, and tremolite and argillaceous slate lie upon its laminæ. It sometimes assumes a brecciated character, as if composed of limestone fragments, and more rarely contains fragments of rocks of the gneiss and mica slate system.

It is the fruitful source of statuary and architectural marble, contains a great variety of minerals, and is locally traversed by veins of quartz, felspar, and granite, and by veins of cobalt, galena, iron.

Contains no organic remains

The limestone associated with gneiss and mica slate is usually, perhaps always, destitute of organic remains; while part of that associated with clay slate almost invariably contains shells, trilobites, or corals. The gneiss and mica system may therefore be considered as *hypozoic*, or beneath the strata which contain reliquiæ of life; while the clay slate system is clearly *epizoic*, or within the zoological era. But this distinction, when applied to such vast thicknesses of rock devoid of these remains, and variously alternating, is rather doctrinal than practical, and being founded solely on a comparison of the calcareous strata, we shall so restrict any use which we may find it convenient to make of these terms. They are besides theoretical terms; for if we suppose the crystalline limestones devoid of organic remains, to have derived their peculiar texture from changes subsequent to their deposition, under the influence of subterraneous heat, it is possible that the absence of organic remains may be often a consequence of this change. This is possible; at the same time it must be owned, that circumstances hereafter to be mentioned concerning the limestones of the slate system above, appear strongly confirmatory of the hypothesis which these terms involve.

What observations remain to be made on the other rocks associated with grieiss and mica slate will be found in the following section.

Districts of the Gneiss and Mica Schist System.

The extent of Countries occupied by gneiss and mica schist with their associated rocks is enormous; and there are few districts of sufficient area where granite appears, without being followed by these deposits. But the order of their succession, and their relative thickness, are very uncertain. In some districts gneiss, in others mica slate, in others quartz rock, make up the whole visible system, and are immediately succeeded by clay slates. There are even cases where the whole system is wanting, and large areas of granite are immediately invested by clay slates and limestones containing organic remains. In England, for example, gneiss and mica schist, and primary limestone, and quartz rocks, are almost unknown; but in Ireland, and especially in Scotland, they are abundant, and include among them many gradations, chlorite slate, talc slate, hornblende slate, &c.

In England, &c.

In Cornwall and Wales the granitic rocks are almost universally succeeded by modifications of clay slate; and though in Cumberland the granite of the river Caldew is indeed covered by rocks, having the character of gneiss, mica schist, and dark hornblende slate, (provincially called whintin,) their area is inconsiderable, and the latter rock soon changes to clay slate. At a place called Martindale, at the Eastern foot of Caldbeck Fells, is a fine-grained variety of gneiss in very thin, straight laminæ.

Granite veins are rarely known to divide any of the

rocks of this region. Quartz rock occurs in the Lickey Hill near Bromsgrove, and gneiss and quartz rock were found by Mr. Horner bordering the granite of the Malvern Hills.

The general order of succession among the primary strata in Scotland may be represented in a diagram as in pl. i. fig. 12, but it must be remembered that all the terms of the series are seldom coexistent in the same vicinity.

Gneiss in Scotland.

Gneiss is abundant in Scotland, particularly in the Northern and Western parts, and being exceedingly variable in composition, is very often undistinguishable from mica schist, under which head apparently M. Boué has preferred to class many of its varieties.

Gneiss constitutes almost the whole mass of Iona, Tiree, Coll, Rona, and the Hebrides, and enters largely into the composition of the Zetland Isles, which are in some measure to be viewed as a prolongation of the Hebridian group, as the Orkneys appear to be an extension of the Eastern rocks of Caithness. Housa, Burra, Whalsay, Out Skerries, and Yell, and the Western parts of Fetlar and Unst, and part of the Mainland of Zetland, are gneiss. The remainder of the Mainland is principally mica slate, and the two rocks are partially separated from each other by an interrupted deposit of limestone. The gneiss is often porphyritic, as in Unst; at Hagrasattervoe (Hibbert, *Edin. Phil. Jour.* vol. ii.) it appears to contain masses of granite as well as to be traversed by veins of sienite and talcose granite. Kaolin is derived from it in the Mainland and in Fetlar. Gneiss exists likewise in the Orkneys around the granite of Stromness. (Boué.)

In the Hebrides this rock changes often from the typical mixture of quartz, felspar, and mica, by the substitution of talcose minerals and hornblende for mica, by the omission of the quartz, and by the interlamination of argillaceous schist. Some varieties are extremely slaty, and suffer rapid decomposition; others approach nearer to granite, and present rude and naked surfaces and precipitous faces, with few brooks and little alluvium. The direction of the strata in the Hebrides is North-East and South-West, but the declination is obscured by frequent contortions, which in Macculloch's opinion are most frequent in the vicinity of the granitic veins which divide all the gneiss rocks, except those which are associated with clay slate; and the drawing which he presents of the contorted laminæ of gneiss and hornblende slate, in connection with ramifying granite veins, near Cape Wrath, seems to justify his views. The laminæ of gneiss are often peculiarly bent, or apparently dislocated along the line of the veins; and sometimes masses of this rock are curiously enveloped in their substance.

The veins are not often filled with granite of the ordinary kind, but with a compound rock, in which felspar highly predominates, so as to form in several places (Harris, South Uist, Rona, and Coll) a real graphic granite, which in Coll contains garnets. Veins of quartz, occasionally metalliferous, likewise traverse the gneiss of Coll and Tiree. Garnet, rose quartz, zircon, hornblende, epidote, fluor spar, iron pyrites, and sulphuret of molybdena, occur in the gneiss.

Mica schist is not abundant in the Hebrides, but in Rona, Coll, and Tiree, it alternates universally with the gneiss.

Gneiss occurs in many places, as round the granitic mountains of Bræmar and Lachin y gair, at Kincardine in Ross-shire, and other points in the extreme North of Scotland; but the most abundant and interesting deposit adjoins to the granite of strontian.

It forms the beautiful and picturesque region around Loch Sunart, which strongly resembles the Trosachs of Loch Katrine, being equally rich in wood, and remarkable for intricate confusion of rugged surface.

The curvatures to which its laminæ are here subject are very numerous and extraordinary, veins of quartz, felspar, and granite are extremely common, garnets abound in it at certain points, and the metalliferous veins with carbonate of strontian, harmotome and remarkable calcareous spar are highly interesting. On the Eastern side it is bounded by porphyritic masses, but in other directions appears to be overlaid by mica schist, to which its composition approximates.

Mica schist in Scotland.

But the principal part of the Highlands is occupied by the mica schist formation, whose strata, ranging with more or less regularity North-East and South-West, notwithstanding the interruption to their continuity by the unstratified rocks of the Bræmar mountains, and the groups of Ben Cruachan and Ben Nevis.

The South-Eastern limit of this vast deposit is the line of the foot of the Grampians from the Forth of Clyde to Stonehaven. Deposits of red sandstone, lias and a carboniferous part of the oolites border the Eastern coast from the River Spey to Duncansby head, and extend through the Orkneys; rocks of igneous origin, associated with the preceding, mostly occupy St. Kilda, Skye, Rum, Eigg, Mull, parts of Ardnamurchan and Morvern. Within these limits, and with the exception of irregular masses of igneous rocks and of gneiss, the whole of the vast space belongs to the mica slate system, with its included quartz rocks, limestones, serpentines, potstones, its associated hornblende and talcose slates, and its overlying clay slates.

The mountains of this system of rocks are formed into little groups separated by deep valleys and long lakes, and their bases being usually and thickly covered with birch, underwood, and sometimes with forests of oak, while their summits rise often more than 3000 feet above the lakes, the beauty of the scenery is admirable. Scenes, indeed, of an alpine character are very rare in Scotland, and, perhaps, nowhere occur except in the Cuchullin mountains of Skye and the granite peaks of Arran; but very grand and imposing effects are produced by the combination of narrow woody defiles, precipitous slopes, and rocky crested summits. The general outline of the mountains is pyramidal, but this form, elegant at a distance, is broken on a near survey by fantastic projections, and bare cliffs, and by numerous channels, which after storms are changed into a multitude of waterfalls. The valleys destitute of lakes are usually wild and barren, and covered with scattered rocks.

Several of the most remarkable valleys in the Highlands follow the ranges of the strata, as for example, the extraordinary valley of lakes which are united by the Caledonian Canal whose highest summit is but 90 feet above the sea, the valley of the Spey, *Glen Tilt*, Loch Tay, Loch Long, Loch Fyne, Loch Awe. M. Boué observes, that the longitudinal valleys are remarkably narrow as if mere slits in the country, while the numerous transverse valleys are in general more widely expanded.

One of the most interesting valleys in Scotland is Glen Roy, rendered classical by Macculloch's description

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in the *Geological Transactions*. Two narrow, parallel, contiguous terraces, perfectly level and continuous along the whole length of the glen, mark the higher part of its bordering slopes with a singular and most surprising character, the effect of ancient local operations of level water; most probably an included lake, whose lofty barrier at first subsided a little, and then gave way altogether. It has been with less probability conjectured that these lines are the traces of the ancient margin of the sea, left uninjured during a subsequent elevation of the whole country to the extent, perhaps, of 1000 feet. By the natives of these wild regions they have been traditionally supposed to be the works of man in the fabulous Ages.

As might be expected, the forms of the mountains, and especially the shape of their summits, is considerably characteristic of the kind of rock which constitutes them. Compare, for instance, the irregular head and broken slopes of the Cobler and other mountains of mica slate, with the smoother sides and less angulated chloritic top of Ben Lomond, and the conical summits of quartz on Benan, Schehallion, and the Paps of Jura.

Neither are the features of the valleys and waterfalls independent of the nature of the rocks which they traverse. The unequal hardness of mica slate, in particular, is often evident in the rapid streams, by singular hollows and pits in their course, and deep cavities under the cascades. A waterfall near Loch Earn Head exhibits this feature very remarkably.

The most important point of view under which mica slate can be considered mineralogically, is the well-known variation and entire change of character to which it is subjected by alteration in the proportions and permutation in the nature of its ingredients. It cannot be thought surprising that a rock, constituted probably of the débris of many granitic aggregates, should be extremely various in its composition. M. Boué is of opinion, that we may observe on a great scale these variations to be dependent on the general principle, that in proportion to its antiquity or proximity to granite, mica schist becomes more felspathic and more quartzose, in fact, more like gneiss; and on the contrary, that in proportion as it recedes from the fundamental rocks, it becomes more talcose, more chloritic, more argillaceous, in fact, more like clay slate.

Examples of gneiss-like mica slate are found in Glen Tilt, Dalnacardoch, and many other points of the Blair Athol Country, near Tyndrum, and sparingly around the granite mountains of Arran.

In some specimens (Glen Roy) it appears composed of little else than mica folded and twisted round garnet crystals, in other cases (Ben Nevis) the garnets form almost distinct layers. In some cases (Glen Roy) the white mica and quartz form very smooth and attenuated laminæ, in others (Trosachs, Loch Earn) the quartz is in thick irregular plates, which mark one of the gradations to quartz rock.

Quartz rock in Scotland.

Quartz rocks and quartzose mica slates are seen, in the North of Scotland, in Moidart, along Loch Shiel and Loch Eil, and the Eastern side of Loch Linnhe. Above the granite of Glen Tilt, quartz rocks abound in Ben y gloë, and several mountains round the granite of Braemar, and may be well studied in the valley of the Bruar near Blair. They reappear in Mount Alexander and on the sides of Loch Rannoch, constitute the pyramidal summit of Schehallion, and on the borders of the granitic desert of Rannoch Heath are traversed by granitic and porphyritic veins. Further West the Island of Jura is distinguished by the obtusely conical quartzose mountains called the Paps of Jura, and the same rocks extend into Isla. Dr. Hibbert has described the quartz rocks in Zetland.

Talcose slates in Scotland.

Talcose and chloritic slates, holding an intermediate mineralogical character between clay slates and mica schists, also for the most part occupy the intermediate geological position. They may be well studied on the banks of Loch Lomond and Loch Fyne, and several points on the South slope of the Grampians, where they are often rich in quartz, and remarkable for minute undulations and greater contortions. Chlorite slate is also found in the Long Island, and in Fetlar and Unst. The mica schist of the Highlands very generally contains garnets, which are of various size and occur under different circumstances. It seems difficult to explain the very common association of garnets with mica schist and gneiss, except by admitting that this mineral is one of the effects of heat applied to those rocks since their deposition.

Hornblende slate in Scotland.

Hornblende rocks, especially hornblende slate, occur in various combinations with mica slate. Hornblende is seen plentifully in Glen Tilt, and is much traversed by granite veins, on both sides of the Pass of Killicrankie, South of Schehallion, North of Ben More, in the upper part of Loch Lomond, and under Ben Cruachan.

Serpentine in Scotland.

Serpentine, a rock whose geological relations are very imperfectly understood, occurs in Scotland at many places; accompanied generally with talc or steatite, and diallage rock. It is said by Boué to be most frequently placed among the upper beds of talcose slate, though occurrences of serpentine, in small quantities, accompany the limestones of Iona, Glen Tilt, Harris, and Tiree. (Macculloch.) On the South side of the Grampians it occurs only at Cortachie on the North Esk, but through the North of Scotland its localities are more scattered. (Near Drimnadrochit, near Inverness.) The serpentine of Portsoy, said to be employed in some of the apartments at Versailles, forms "three vertical beds," one of them enclosed between hornblende rocks, another between hornblende rocks and primary limestone, and the third between quartzose talc slate and mica slate, which is covered by beds of limestone, hornblende slate, and talc slate, and the junction of all these rocks is softened by a mutual exchange of ingredients. In Scalpa, an irregular, highly inclined bed, one hundred yards thick, of serpentine traverses the gneiss promontory of the lighthouse, and exhibits at its boundaries against the gneiss abundance of hornblende crystals, layers of talc slate, and a sublaminated structure. It contains steatite, asbestus, &c. The granite veins here observed traverse both the gneiss and its included serpentine, and in the latter rock talc is superadded to the ingredients of the vein.

Serpentine exists also in Lewis, and occurs in Zetland in considerable abundance and beauty, both in the Mainland, in Fetlar, and at Brassa Sound in Unst, where it contains chromate of iron in sufficient abundance to be of considerable value in commerce.

Potstone is found in Glen Elg opposite to Skye, and in the serpentine of Scalpa. But the most remarkable rock of this kind is found at St. Catharine's near Inverary, on the opposite side of Loch Fyne. It is imperfectly slaty, and has been employed in the erection of the mansion of the Duke of Argyle. Boué also adds as localities, the districts of Strathearn and Breadalbane.

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Primary limestone in Scotland.

Primary limestone. One of the most important of the subordinate or interrupted rocks which diversify the vast surfaces of gneiss and mica slate in Scotland remains to be noticed. So much has been before said on the composition of this rock, that we shall here dwell chiefly on the question of the relative ages of the different deposits. In the absence of organic remains, we can only examine the associated rocks, and the texture of the limestone itself. The white marbles of Iona are found in a system of rocks by some referred to mica slate, but considered by Macculloch to be gneiss. The variously coloured marble of Tiree with its imbedded augite and hornblende lies in a system of alternating gneiss and mica slate. That of Glen Tilt, characterised by its accompanying tremolites, lies in a quartzose mica slate, associated with hornblende slate. Notwithstanding the want of agreement in character between the limestones, and the more important differences between the rocks which enclose them, some Geologists think these limestones are of the same age.

Boué, following up the notices of Macculloch, traces the line of the Glen Tilt limestones to the East and to the West. In the Western direction they proceed from Gow's bridge, crossing the hills at Lude, tending toward the South, passes through the Glen of Fincastle and across the valley of the Tumel. It is conjectured that limestones of the same range continue by Mount Alexander, and the base of Schehallion, from whence it proceeds through Glen Lyon to the side of Loch Tay, at the foot of Ben Lawers, reappears in Crien Larich, at the entry of Strath Fillan to the West of East Tarbet, in Knapdale, and the head of the valley of Croë.

Eastward from Glen Tilt, this limestone is traced in the course of the North Esk, and in the valley of the Dee near Bræmar, &c.

So extensive a range of limestone rocks in the direction of the strata of mica slate, seems, indeed, to require no additional evidence of its being throughout a contemporaneous deposit. The limestones on Loch Laggan and Loch Eil in Inverness, and at numerous other points in Aberdeenshire, are referred by Boué to the same era.

Second range of primary limestone.

A second range of limestones, lying chiefly in argillaceous and chloritic varieties of mica slate, is considered by the same author to be of more recent origin. The points are near Blairgowrie, at the foot of Ben Vorlich on the North side of Loch Earn, Balquhidder, Inverary, Knapdale, and Lorn, and the limestones of Balahulish, Cairndow, and Dalmally, as well as those which run from Boharm to Bamff, are classed with these more recent limestones.

Perhaps the relations between all these points may not have been correctly ascertained. In every attempt to trace a *contemporaneous line* through the older strata devoid of organic remains, much must be trusted to vague analogies; but there seems excellent reason for admitting that these calcareous rocks, like those which are more perfectly traced among the newer strata, were the produce of a few definite periods, and not mere irregular formations having no relation to each other in respect of time.

The granite of the Isle of Man is followed by very little gneiss, mica slate, and quartz rock. The mica slate is traversed by veins of quartz and schorl. (Henslow, *Geol. Trans.*)

North of Ireland.

The older strata of the North of Ireland may be considered as in part a prolongation of those of Scotland; thus the extensive formation of mica slate in Londonderry and Donegal is on the line of the chain of the Grampians, continued through Jura and Isla; and the clay slate ridges which border the Mourne mountains, run in the direction of the Mull of Galloway and the clay slate chain of the South of Scotland, while between these two systems of slates are carboniferous limestone, red sandstone, and other strata of newer origin, corresponding to those which separate the analogous chains in Scotland.

The mica slate rocks are principally of the talcose varieties without garnets, but producing hornblende. Deposits of laminated primary limestone of different colours, containing talc, quartz, hornblende, or pyrites, with veins of quartz, chlorite, and calcareous spar, occur in the mica slate, in many parts of Antrim and Londonderry. Hornblende slate likewise forms distinct beds in the mica slate of this region, and felspar porphyry is described under the same circumstances. (Berger, *Geol. Trans.*)

South of Ireland.

In the South-Eastern part of Ireland, granite is extensively seen, and mica slate forms two ranges along its Eastern and Western boundary, and wherever it occurs is in direct contact with the granite. On the Eastern side of the granite it runs in a narrow course North-East and South-West, dipping steeply South-East, and consists of alternate layers of mica and quartz of extremely variable thickness. On the Eastern brow of Rochetown Hill mica slate runs into a natural hollow of the granite, still retaining the North-East and South-West direction of its strata. On Maulin Hill it is singularly and fantastically contorted on the small scale. There is a prolongation of the body of mica slate at the head of Glenmacanass, gradually narrowed in its Western progress, and constituting a wedge-like mass, inserted into the body of the granite, and enclosing a seeming bed of granite six to ten yards in width, besides irregular masses of granite incorporated with the slate. In the same vicinity greenish, sectile, talc slate lies imbedded in the mica slate, and is used for various purposes of architecture and sculpture.

In Glenmalur occurs a remarkable instance of decided alternation of granite and mica slate under circumstances very favourable for its display. In a space of 208 fathoms no less than five distinct alternations of granitic beds, with as many layers of mica slate, are clearly traced, and several of these beds are compound, or really made up of similar alternations of granite and mica slate, or quartz and mica slate. The great mass of granite is below, and the great mass of mica slate above, constituting the hill called Lugduff. Grenatite abounds in this slate.

Similar alternations occur in other neighbouring places, making a total thickness of one-third of a mile, and the whole system ranges North-East and South-West, and dips South-East. On the North-East they probably abut, and terminate against the granite. The mica slate on the summit of Lugnaquilla is likewise interstratified with granite. Clay slate bounds *it on the* East, and at length, coming into contact with the granite cuts off its further progress to the South.

On the Western side of the granite the mica slate is still less extensive. It is found to enclose beds and elliptical masses of granite in Glenismaule; and it is mentioned that a granite vein, four to eight inches wide, ranging 25° North of West, cuts off the mass of alternating strata, without occasioning any displacement. In

the same valley are two distinct beds of compact greenstone porphyry in the mica slate, one four feet wide, the other two feet. Andalusite abounds in the mica slate of this country, and greenstones of various kinds alternate with it.

The frequency of the phenomenon of alternation between mica slate and granite is a singular feature in the Geology of this part of Ireland, for the full display of which we are indebted to Mr. Weaver. (*Geol. Trans.* vol. v.)

In Brittany.

The tract of old rocks in the North-Western part of France is one of the most extensive in Europe. The granite, generally the most elevated, is separated from the secondary strata by a system of gneiss and mica slate, and by another system, into which they pass almost indefinitely, of clay slates. In the Departments of Calvados and La Manche these two systems appear as zones around the granite, the gneiss being within the clay slate. Quartz rocks of blue colour, and pegmatites with tourmaline, are associated with them, and veins of quartz and granite traverse them. (De Caumont, *Geol. du Calvados.*)

In the Pyrenees.

The granitic masses of the narrow chain of the Pyrenees having been uplifted in much confusion, are very irregularly bordered; in several places they are overlaid by gneiss and mica slate, but generally by the clay slate series. Charpentier, a disciple of Werner, thinks the gneiss of the mountains which border the valley of Soulan, so intimately connected by gradation and alternation with the subjacent granite, as to be necessarily united therewith into one formation. In many instances gneiss and granite are described as alternating in very thin layers. In other cases, vast blocks of micaceous gneiss of 100 cubic fathoms' bulk are buried at intervals in granite, always preserving one constant relative position or direction of strata. These are thought by Charpentier to be of contemporaneous origin with the granite, which passes into them at the sides, and thus interlaminates the gneiss.

Mica slate, in the same manner, is intercalated with granite in a great many places, and quartz and felspar bands occur in the granite. In many places in the Pyrenees the "granite" contains beds of stratified granular limestone, (such as in other districts lies in the gneiss,) with graphite, talc, fluor spar, mica, hornblende, &c.

The more modern view of these phenomena is that they are quite consistent with the doctrine that granite is an igneous, but gneiss and mica slate originally aqueous rocks, and that in some cases what is called granite, is in fact gneiss with the aspect of granite, derived from a more than usual condensation and greater effect of heat. M. Boué, Dufrenoy, and other writers, have proved beyond a doubt the powerful action of heat along the Pyrenean chain, as evinced not only by the usual subcrystalline character of the clay slates, but also by the metamorphism of the chalk into the characters of primary limestone, with abundance of metallic and granitic veins at the line of junction of the altered stratified and the igneous rock. The age of the eruption of granite along this chain is, by observations of Dufrenoy, determined to be, at least in part, posterior to the chalk.

It is extremely probable that the same kind of explanation will be found to apply equally to the alternation of granite and slates in Ireland and Cornwall, and to the alternations of porphyry and slate in Cornwall, North Wales, and Cumbria. It is to be remembered, however, that the igneous theory, as it has been termed, does not by any means require that all these beds of seeming granite should be pronounced to be altered gneiss, nor that the beds of porphyry should be considered as altered clay slate. Alternating igneous and aqueous action is perfectly intelligible, and exemplified in modern operations of Nature; but certainly in many cases, both in Cornwall and Cumbria, it appears the more correct view to suppose a gradual and partial *rearrangement* of the materials of the rock, through the long action of heat. This would well agree with the indefinite boundaries of the porphyries of Cornwall and Cumbria, which often pass by insensible modifications into ordinary slate.

In central France.

The great central plateau of old rocks in France from which the Loire, Vienne, Dordogne, &c. take their source, is chiefly a granitic and porphyritic tract, surrounded by oolitic and carboniferous rocks, but clay slates and gneiss rocks appear in the valley of the Vienne, and occupies a large part of the Southern boundary. Near Limoges are alternating beds of granite and gneiss, and some subordinate beds of pegmatite and hornblende rock; the gneiss passes by one variation to granite, by another to mica slate. The ranges of the strata near Limoges are North-East and South-West, and they are crossed by decomposing elvan courses to North North-East. Tin veins occur near Vaulry in gneiss as well as in granite. Towards the borders of the district the gneiss becomes less granitic, more associated with hornblende slate, and encloses deposits of micaceous limestone. Serpentine lies in this gneiss in many places, and M. Cordier appears disposed to refer them all to one contemporaneous, though interrupted deposit. The pegmatites and kaolins, which have resulted from them by decomposition, of St. Yrieux, form numerous veins and strings in the gneiss and hornblende slates, which sometimes intercalate themselves between the laminæ. Quartz rock of bluish colour exists likewise in the Black Mountain and elsewhere. Oxidulated iron abounds at many points in the gneiss; galena, phosphate of lead, carbonate of copper, antimony, and hematite, are the products of the veins. (Desnoyers.)

The most remarkable alterations of secondary limestones take place, according to Dufrenoy, along the line of junction with the granitic and porphyritic masses. Thus the lias and oolite become metamorphic, and are traversed by metalliferous veins, as in Cornwall and Brittany, where the slates are metalliferous principally in the same situation.

Other localities in Europe.

After these details of the circumstances attendant on gneiss and mica slate at so many interesting points, we shall only add some general observations on the range and extent of this system of rocks in other Countries. Gneiss and mica slate in small quantity occur in the Vosges, and gneiss more abundantly in the Black Forest.

The long irregular chain of the Alps contains a vast quantity of gneiss and mica slate, variously extended around the talcose granite cores of Mont Blanc and St. Gothard, from the Mediterranean almost to the Danube.

Deeply buried beneath the valley of the Danube, gneiss and mica slate do not reappear around the granitic origin of the Carpathians. Their place is supplied in this chain by a vast deposit of clay slate.

The primary mountains which encircle Bohemia are

on all the Southern half granite. Gneiss and mica slate are superadded on the West, and the former rock in particular abounds in the Erzgebirge. The Riesengebirge granite is bordered on the North by gneiss, on the South and East by mica slate, and these rocks are associated with granite in the range which divides the drainage of the Oder and the Elbe.

These rocks are most extensively spread over the Northern parts of Europe, from Copenhagen round the Gulf of Bothnia, along the Uralian chain toward the Caspian Sea and the Caucasus.

In America.

In America, Humboldt describes gneiss as less abundant along the high chains of the Andes than along the inferior mountains of Caracas, in Oronoko, Brazil, New Spain. It is occasionally auriferous, and contains micaceous, primary limestone. The most considerable masses of mica slate mentioned by this distinguished traveller are those of the Cordillera of the shore of Venezuela. This formation in the Andes is less rare in the North than in the South of the Equator. No where, perhaps, is the total suppression of mica slate formations more frequent than in the Cordilleras of Mexico and South America.

The Eastern primary range of North America passes through the United States from the St. Lawrence to the Mississippi in a direction nearly parallel to the coast, and generally 100 miles distant from it.

Gneiss is the most extensive of the primary strata in the Northern States of America, filling large tracts in New Hampshire, Massachusetts, Connecticut, the Highlands of New York, Pennsylvania, Virginia, &c. and the Southern Counties. It retains in general its place next to the granite, and is often succeeded by hornblende rock. It contains deposits of primary limestone, "calcareous sandstone," and in several places, laminated plumbago, adularia, zircon, magnetic iron ore.

It is traversed by veins of granite in Haddam, full of beryl, schorl, and other minerals.

Mica slate is less extensively spread, and occupies a narrower course in Massachusetts, Connecticut, the Highlands.

Talcose slates succeed, and granular limestone appears in ranges above it in Connecticut, Pennsylvania, and Maryland. It is often magnesian or dolomitic in Massachusetts and Connecticut.

Quartz rock occurs in the Western part of Massachusetts.

Slate System.

Inversely proportional to the gneiss and mica schist.

It may be taken as a general rule that the two systems of rocks which compose the primary strata are inversely proportional to each other. Countries which abound with gneiss and mica schist are indeed seldom quite devoid of clay slate; but they also seldom contain it in great quantity. On the contrary, where clay slate is extremely abundant, gneiss and mica slate are less extensively developed. This is at least very much the case in the primary mountains which surround and diversify the basin of Europe.

In Scotland the Grampian ranges, and, in fact, all the Northern primary strata of that Kingdom, are principally composed of mica schist and gneiss, while clay slates prevail almost exclusively in the Southern chain of the Lammermuir and Galloway ranges. As before observed, the mica slate system in Ireland is distinct from the clay slate tract. The Cumbrian granitic rocks are surrounded by clay slates in great plenty and variety, but there is little gneiss or mica slate. The same is observed in the large primary tracts of Wales, Devon, and Cornwall, and it is a characteristic feature in the Geology of the Harz.

Cumbrian slate district.

For the purpose of clearly unfolding the relations of the various argillaceous, calcareous, and conglomerate rocks which compose the vast and variable mass of the clay slate system, it is desirable to fix our attention upon some district where the variety of the rocks is considerable, and the order of succession is perfectly known. Such is the district which overlooks the Northern English lakes. We shall, therefore, describe it as a type of the clay slate system, and refer to it as a constant term of comparison.

The granite of Skiddaw is covered by gneiss and hornblende slates. The latter rock gradually changes to the chiastolite slate and other argillaceous slate of Skiddaw. The argillaceous slates here commencing form a series of three members, distinguished by their mineralogical characters, and a constant order of succession. See pl. i. fig. 13.

Dark lowest slates.

The lowest slate rocks of the system range to the South-West from Skiddaw and Saddleback by Grisdale Pike to Dent Hill, filling the valleys of Derwentwater and Crummock water. South-West of Buttermere, they are concealed by the elevated ranges of High Steel and Red Pike, but reappear in the lower parts of Ennerdale, and abut against the limestone border near Egremont.

The slate of this district is generally of a dark bluish colour, and of very uniform texture, soft, fine-grained, and very fissile, and has been employed in the vicinity of Keswick and Hesket Newmarket for roofing houses; but for this use it is not very suitable, for it easily perishes in the atmosphere. In consequence of its want of durability, the mountains of this slate have smoother contours, more uniform slopes, and a more verdant surface than those of the following series.

In one point on the South-Western edge of Derwentwater we have observed an undulated variety of this slate of paler colour and more shining surfaces, indicating an approach to the nature of chlorite slate. Chiastolite is imbedded in the lower part of the rock in Skiddaw and Bowscale Fell. Where this slate shows itself by the sides of the lakes, its laminæ appear to be generally vertical, and often flexuous. Veins of quartz are frequently seen penetrating and interlaminating its masses. In several places they yield abundance of lead ore; and in the district called Newlands, abundance of carbonate of copper, and some cobalt. Mr. Otley states that the lead veins run North and South, and those of copper East and West. Steatite is found in Borrowdale, and mixed with the slate in Martindale. Two salt-springs have been detected in it near the upper end of Derwentwater.

Green middle slates.

These rocks, sloping to the South-East and North-West from Skiddaw and Saddleback, are covered by the middle system of slates. These are best developed on the South-Eastern slopes, and occupy a long range of mountains parallel to the Skiddaw slates, in those highly picturesque and romantic valleys wherein the lakes of Ulswater, Haweswater, Thirlmere, and Wastwater, spread their beautiful waters.

The lowest rock belonging to this system is a red, argillaceous, fissile stratum, abundant in the Eastern shores of Derwentwater, especially about Barrow and in St John's Vale, in both localities resting upon the Skiddaw slate.

Geology. Ch. II.

Red rock.

It is a very singular rock, characterised universally by its mottled colours, and apparently heterogeneous composition. Its first aspect reminds us of an old red sandstone conglomerate, but on closer inspection the seeming certainty of its brecciated character vanishes; the seeming fragments of which it is composed appear to be scarcely more than colour spots, and we leave the rock very undecided as to its origin. In some cases, however, it must be owned, the appearances of aggregation are very difficult to withstand. It is distinctly stratified, with dip to the South-East, and is of considerable thickness. Its pervading tints vary from bright red to purple, and in proceeding up Borrowdale, rocks succeed in the same geological position, at first blue, and afterwards greenish, while the seeming conglomerate aspect becomes less distinct, the spotting is smaller, the hardness greater, the rock splits vertically, and becomes, in fact, a coarse green slate. Amidst the numerous varieties which succeed, we perceive about the Bowder stone some remarkable laminated beds, with talcose surfaces, and variegated with nodular concretions of calcareous spar, green earth, and differently coloured quartz or calcedony, having altogether very much the aspect of amygdaloid. This peculiar slate, which seems to indicate the united agency of water and great heat, dips in the same direction as the red rock of Barrow, and thus helps to prove that in this tract the vertical cleavage of slate is transverse to the lines of deposition. It appears to harden and change character in Wallow Crag. There are, perhaps, repetitions of this remarkable rock in other parts of the slate systems, since it occurs at the upper end of Ulswater, in Helm Crag, Loughrigg, and other points about Grasmere and Elter Water, in Ulpha, and other places. But it is possible that these may be the same beds; a conjecture supported by the fact, that red rocks, like those of Barrow, lie beneath them at Grasmere. And, indeed, in Helvellyn and other mountains we see the coarse slate rock vary through all appearances from amygdaloidal slate to fragmentary greywacke, and this again assuming more regularity, resemble clay porphyry, from which its uncrystalline felspar and recurring fragmentary structure do not always clearly distinguish it. On the other hand, we see the coarse rocks of Borrowdale and Patterdale lose their spotted aspect, become more uniformly green, more regularly fissile, and change to the fine-grained green slates of Langdale and Coniston Fells, or the pale grey rocks around Grasmere, or the "rain spot" slate of White Moss.

Greenstone rocks are variously associated with this system of slates, sometimes in the state of dykes, sometimes as overlying masses, particularly about Keswick. The sienitic rock of Red Pike, Scaleforce, and Wastdale, which seems to come up through the lower slate, ramifies its masses through and over these rocks. Red porphyry dykes divide them on Armboth Fell; large masses of red and dark porphyry with garnets, lie on their lower portions in St. John's Vale; and if the slate of High Pike belongs to this system, the felspathic (or elvan?) courses there known, may be added to more massive accumulations of igneous products which border Thirlmere Lake. The sienites and hypersthenes of Carrock Fell, and the granitic tracts of Wastdale and Devock Lake, must probably be viewed as rising upwards from below the whole series, and spreading on the surface of the strata of slate.

The minerals which this district yields are rather numerous than valuable. The veins are generally quartzose. A great variety of lead spars, sulphuret and carbonate of copper, with galena, pitchy iron ore, wolfram, &c. are found in Caldbeck Fells, among the slaty and sienitic rocks. Galena has been worked in Griedale, (Ulswater,) copper ores at Coniston and in the lower beds in Newlands, plumbago in Borrowdale, micaceous iron ore in Eskdale, &c.

In consequence of its superior hardness, and its frequent association with igneous products, the green slate mountains assume bolder forms, present more lofty and rugged peaks, and more inaccessible precipices than the softer slates of Skiddaw. For the same reason, the streams instead of furrowing the smooth slopes in straight courses are twisted about among the unyielding rocks, and broken into admirable cascades.

Dark limestone.

The region of green slate is rather indefinite toward the South-East, where it is overlaid by the uppermost series of greywacke slates. Perhaps it may be best to adopt as the conterminous line, the narrow course of dark calcareous slate ("transition limestone") which passes from Long Sleddale by Low Wood Inn and Windermere Head to Coniston Water Head and Broughton Mills. This rock contains organic remains, as caryophyllia, millepora, producta, spirifera, orbicula; but generally in so imperfect a state of conservation that their specific characters are very obscure. The calcareous layers alternate with layers of slate of the same colour, and are with difficulty distinguished from them. Their dip is usually very rapid.

Upper slates.

Above this regular band of limestone lies a thick series of rocks, containing several varieties, all capable of being ranked as greywacke. The lower rocks, very dark in colour, are frequently quarried for slate, (Broughton, Ulverstone, &c.) occasionally for flagstones and tombstones, (near Hawkestone, crooks of lune, &c.) which are sometimes parallel to the stratification. (Otley, *Guide to the Lakes.*) In the long aberrant range of slate rocks beneath Ingleborough and Penygant, (*Geol. Trans.*) dark slate of similar aspect reappears in Clapham Dale and between Ribblesdale, and furnishes enormous tables of slate with nodules sometimes formed round lituites, in the nearly vertical partings or cleavage. At Ingleton the greenish slate seems rather referable to the middle slate system.

Above the dark uniform slates previously described lies a system of more micaceous and more granular rocks, which extend to the South-Eastern border of the primary district. They are of two kinds: 1. fissile with micaceous partings parallel to the stratification, sometimes reddish, and appearing to resemble certain laminated red sandstones. 2. Granular, not fissile, with disseminated mica. These varieties may be observed frequently alternating in the country North of Kendal and about Kirby Lonsdale, and present the most striking analogies to arenaceous freestone and micaceous flagstone. In the upper part of this system (near Kendal and near Kirby Lonsdale) lie layers of shells, or rather casts and impressions of shells of the following genera: orthoceras, patella, trigonia, plagiostoma, pecten, gryphæa, turritella, melania, spirifera, terebratula. (*Geol. Trans.*)

Cleavage of slate.

A very remarkable feature in the region of this upper slate series, is derived from the uncommonly crystalline aspect of the rock on a large scale. The numerous joints intersecting one another at acute angles, and ranging with admirable precision for a hundred yards or

 more, divide the faces of the hills into long ridges of smooth, rhomboidal rocks, alternating with parallel heathy or grassy hollows. This is probably the reason of the peculiarly rough and knotted appearance of many hills of this tract. It is difficult to resist the belief that this is owing to a real crystallization, and that slate is a crystalline rock with definite angles and regular cleavage. But on pursuing the inquiry it will be found that the parallelism of external joints and internal cleavage is a phenomenon of a different kind from geometrical crystallization, not produced in consequence of an original equilibrium amongst the particles, but from symmetrical consolidation of the mass, exactly as the cuboidal blocks of oolite, the rhombs of shale, and prisms of basalt have been formed.

Among the common appearances of cleavage is that represented in pl. i. fig. xiv. where different layers (strata) of slate are cleavable at different angles of incidence.

Scotland. It will be difficult to put the slates of Scotland in comparison with those of Cumberland, as they are deficient in limestone. In general terms it may be said, that the dark pyritous slates of Argyleshire and the West of Scotland seem analogous to those of the lower Cumberland group; but those which constitute the Lammermuir and Dumfriesshire mountains have the characters of the greywacke system.

Ireland. Mr. Weaver describes the slate which borders the granitic tracts South of Dublin, as alternating with greenstone and greenstone porphyry, and enclosing clay slate conglomerates.

In Windmill Hill, Mr. Weaver describes several alternations of a granular felspathic rock with the clay slate. And in the mountain of Croghan Kinshela, in the space of 630 fathoms, are eight principal beds of alternating granite and clay slate, besides several of granite and clay slate mixed, and four of clay slate and greenstone.

Clay slate and quartz rock are likewise seen in frequent alternation on the Eastern coast of Ireland, and thus remind us of the similar rocks in Anglesea. No organic remains have been found in these tracts; but Mr. Weaver describes the occurrence of fossil plants perfectly analogous to those of the carboniferous rocks in coal seams of the South of Ireland, supposed to be included in the greywacke slates.

Isle of Man. In the Isle of Man, Mr. Henslow is inclined to consider in one instance the cleavage and stratification coincident. Elvan dykes and granite veins divide it.

Wales. In Wales, according to Professor Sedgwick and others, the slate system between the old red sandstone and the granite presents the following general characters in a descending order.

1. Greywacke containing, in a state of considerable developement, several divisions, calcareous, arenaceous, and shaly, with organic remains, in considerable numbers and variety. (Buallt, Llandilo.) The layers of the upper part of this rock conduct us by an easy transition into old red sandstone.

2. The great slate formation, containing in all its parts indications of mechanical origin. Detached deposits of limestone.

3. A vast group, differing from the ordinary character of the Welsh mountains, in containing a very large proportion of felspathose rocks of porphyritic structure. Of this the mountains of Snowdonia are probably the lowest portion; they contain organic remains.

4. A group of slaty rocks described by Henslow in Anglesea, consisting of chlorite and mica slates, and quartz rock.

Nearly all that is valuable in the Geology of the slate system of Wales is due to Henslow's description of Anglesea, Sedgwick's labours in Snowdonia, and all its intricate dependences, and Murchison's recent and detailed investigation of the South-East portion of the district from Shrewsbury to the mouth of the Towy. The results of this friendly partition of labours have been eminently successful; while in the North-Western district the general inferiority of position of the chloritic and micaceous schists to the whole clay slate system of Wales is clearly proved; the true place of the Snowdonian shells fixed in the very lowest portion of the clay slate; the extent and effects of subterranean convulsion and intrusion of igneous rocks, very fully pointed out: these phenomena have been linked by discoveries on the other side of the region into a complete system of slaty deposits. The greywacke series on the South-East border, described by Mr. Murchison, fortunately presents a series of phenomena, deficient or not clearly separated in the slate district of Cumbria,—a vast number of organic remains, lying in distinct groups, a series of distinct members of the greywacke, which these fossils appear to characterise, limestones of different ages which clear up the difficulty, always felt hitherto in fixing the true relations of the limestones of Dudley and Llandilo; and, finally, ancient Plutonic operations accompanied by elevations and alterations of the strata. We may now, upon sufficient data, affirm that the Welsh and Cumbrian series of slates presents a nearly complete record of all the principal deposits, with their characteristic organic remains from the gneiss and mica schist upwards to the carboniferous system; and, as these slates graduate below into the mica schist system, and above into the old red sandstone, to show a continuity of marine operations in a part of the geological scale of periods where formerly was an utter blank. Mr. Murchison finds the greywacke series divisible into six groups, in the following descending order, all ranging North-East and South-West.

Groups in the upper slates of Wales. The first group, below the old red sandstone, is a series of thin-bedded arenaceo-calcareous strata, 1000 feet thick, abundant in the neighbourhood of Ludlow, and stored with brachiopodous bivalves of the genera terebratula, strophomena, leptæna, and orthoceras; and trilobites of the genera homonolotus and calymene.

The second group is limestone 100 feet thick, in its upper part interlaminated with the superior beds, and below resting on shale. It is identical with the celebrated limestone of Dudley, contains nearly all its well-known fossils, and ranges in a continuous escarpment for many miles North-East and South-West, but grows thinner continually to the South-West, so that in the prolongation of the strata parallel to the South Wales coal fields this interesting rock is nearly extinct.

The third group is the dye earth of Shropshire, which was once supposed to overlie the Dudley limestone. It is, perhaps, 2000 feet thick, and is made up of incoherent, greyish, argillaceous, sometimes micaceous schist. The higher strata are in some places charged with many orthocerata, lituites, asaphus caudatus, &c Other beds are locally distinguished by concretions of argillaceous limestone formed around corals and other

organic bodies; and toward the base of this deposit a thin, calcareous zone is observed in Shropshire, containing the pentamerus lævis, *Sow.* and a new species of that bivalve.

The fourth group is an arenaceous sandstone series of various colours, chiefly red and blue; calcareous bands are associated with the sandy strata, almost made up of productæ, leptænæ, and spiriferæ, with crinoidal remains, all of species peculiar to this group. Thickness 1500 or 1800 feet.

The fifth group consists principally of black shale enclosing beds of greywacke, flagstone, or calcareous slate, which, prolonged to the South-West, join themselves to the trilobite beds of black limestone and calcareous flagstone at Llandilo, and thus establish the distinctive relations of that rock to the Dudley limestone. The thickness of this group probably exceeds that of any of those mentioned above.

The sixth group is a vast deposit several thousand feet in thickness, consisting of red, coarse, quartzose conglomerates, schistose beds, and purple-coloured sandstone. No organic remains have been yet observed in this group.

Below all these comes the great slate formation with detached masses of limestone, also ranging North-East and South-West, as about Bala lake.

Charnwood Forest.

In Charnwood Forest the sienitic rocks are followed by clay slates of different kinds, compact and coarse, soft and silicious, green or dark coloured.

Cornwall and Devon.

In Cornwall and Devon the order is,

1. Greywacke, with calcareous slaty beds sometimes containing organic remains, and detached deposits of limestone.

2. In two places a serpentine formation, which, in the Lizard, contains diallage rock, talc slate, hornblende slate, and mica slate, appear to occur beneath the greywacke. Its relations are obscure, but it is superior in position to the following formation.

3. The great formation of metalliferous slate (killas) with many subordinate beds of greenstone, felspathic slate, &c. It is traversed by granite veins, and is said to alternate with granite.

Dr. Boase, in his recent Work on the *Geology of Cornwall*, arranges the schistose rocks of Cornwall in two groups, the upper of which is associated with black calcareous slates, and the lower much interlaminated and mixed with porphyritic masses, eurites, quartz veins, &c. At its junction with the granite, the killas is frequently intermixed with granite veins, and is altered in some respects so as to lose in part its fissility, and to be described by the miners as "Elvanny Killas."

The general impression concerning the schistose rocks of Cornwall is that their mineral composition is a mixture of quartz, felspar, and mica; and so, probably, is that of most clays and shales.

The extensive deposit of serpentine of the Lizard is seen in several places to rest upon and alternate with greenstone and porphyry, in others to rest upon green talc or clay slate. At Coverach are rocks of various texture, in some measure intermediate between serpentine and diallage rock, which suggest important reflections on the relation of this beautiful rock; and, in the same place, the greenstone abounds with diallage, and contains likewise titaniferous oxide of iron. Veins of steatite divide the serpentine, and are thought by Sir H. Davy to be derived from decomposed felspar. Dykes of sienite, and saussuritic diallage rock pass through the serpentine.

The clay slate deposits of Brittany are said to resemble those of Cornwall. Very similar serpentine occurs there, and in addition ogygiæ, calymene, euomphali, and posidoniæ.

Two-thirds of the area of the chain of the Pyrenees is composed of clay slate, which appears to exhibit varieties of texture and aggregation like those described in the Cumbrian district, with the exception of the coarser kinds being dark green, micaceous, or granular, aluminous or silicious. Frequently these slates alternate in very thin layers with limestone, in which case a number of calcareous fibres crossing the slate, but not the limestone, give the mass the peculiar appearance of schiste rubanné; limestone abounds with this slate series, and is either compact, slaty, or granular. It contains crinoidal and zoophytic fossils, "ammonites," and a few other shells, and some are found in the alternating slates. Anthracite in small quantities is mixed with the slates, quartzose, felspathic, and greenstone rocks alternate with them. Most of the metallic products of the Pyrenees are found in the clay slate system. (Charpentier.)

Ardennes.

The Ardennes mountains, which cover so vast a tract in France, Luxemburgh, and the Rhenish Provinces, and which support the volcanic products of the Eyfel volcanos, are mostly composed of greywacke slate analogous to the upper part of the Cumbrian system. Good roofing slate is not common in this tract. Remains of ferns, like those of the coal beds, of productæ and encrinites occur in it.

Rhine valley.

Organic remains are not very rare in this formation on the banks of the Rhine. In the valley of Niederlahnstein we found the greywacke slate rich in fossils, among which spiriferæ were most numerous. The lower part of the slate series of the Rhine appears to be the most quartzose, and it will be found occasionally difficult to say whether a particular rock should be called greywacke, or quartz rock.

Harz.

The slates of the Harz contain productæ, calymene tristani, posidonia becheri, &c.

Scandinavia.

The slate system of Scandinavia presents a general analogy with that of Cumberland. In its upper part are black limestones in nodules or beds alternating with slate and containing trilobites of the genera paradoxites and agnostus, and orthoceratites.

Tarentaise.

The group of the Tarentaise, referred by MM. Brochart and De Buch to the age of transition rocks, is very dissimilar from the general character of the deposits of that period. Consisting of granular and talcose limestones, gneiss, and mica slate, it may be compared to the earlier primary rocks, while the organic remains sometimes found in it, and the coarse greywackes which belong to it, unite it to the latter period of the system. (Humboldt.) Similar remarks are applicable to the metamorphic strata of the Valorsine, and perhaps, in both cases, the peculiarity of aspect is much dependent on the local influence of heat derived from the neighbouring granitic masses and veins.

North America.

Clay slate is the lowest rock in North America containing organic remains, which are always of marine origin, and it rests immediately upon granular limestone. These remains are extremely rare: brachiopodous bivalves and orthoceratites are found at Troy. This rock may be traced over a space of two thousand square miles in the Counties of Saratoga, Schenutady, Albany,

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Rensselaer, and Columbia. It extends into the Western margin of Massachusetts, and there rests immediately on granular limestone. (Eaton.) Its laminæ cross the planes of deposition as in the slates of England, and all the accidents to which the European slates are subject are repeated in America. It is silicious about Hudson's. Clay slate is not extensive in South America.

Transition Limestone.

Analogous to older primary limestones

The limestones associated with clay slates are almost universally known to Geologists by the name of Transition Limestone, a term which we think liable to little objection, even by those who reject the title of Transition Strata, as applied to the whole or any considerable part of the slate system. These limestones are usually, as in Norway and Cumbria, of a very dark colour, fetid when struck, and more or less associated by alternation and gradation of characters with the slate rocks; or they are mere calcareous slate, as in some parts of South Wales; or they form considerable rocks, as in the Eifel, at Dudley, in Shropshire, and Herefordshire. There are also in North Wales and Devonshire portions of limestone more analogous in character to the primary limestone, and like that very limited in extent, appearing like huge ellipsoidal concretions wholly enveloped in slate. These latter, like primary limestone, are generally deficient in organic remains; they appear to range parallel to the original planes of stratification in the slate, and may thus eventually be found of great use in subdividing that thick system of deposits They may be considered as generally, perhaps universally, more ancient than the more connected range of limestone and calcareous slate with organic remains. It is in the upper part of the slate series in South Wales, Herefordshire, and Cumberland, that the limestones with organic remains are found.

by the manner of its accumulation.

But even the most connected portion of this upper transition limestone is liable to so great alteration of quality and variation of thickness as to present some points of analogy to the earlier calcareous deposits. From very thin and unimportant traces above the Vale of Towy, the uppermost limestone swells out to a considerable thickness in Herefordshire, Shropshire, and Dudley, and the number of organic remains varies in the same proportion. About Ludlow the thinner beds of this limestone occur principally in nodules united with much shale, both containing orthoceratites, trilobites, &c. Even amongst the thicker beds of the limestone rock, Mr. Murchison has recognised the same remarkable tendency to ellipsoidal concretions.

The transition limestone of the Hartz presents two considerable independent masses, enclosed between conformed strata of greywacke. Near Rütslau, East of the Brocken, it abounds in madrepores, which, however, are chiefly rendered visible by decomposition of the rock. This character also obtains in much of the dark limestone of Norway and of the Cumbrian lakes. The laminated limestones of South Wales and the Eifel, are of a lighter colour, and generally associated with shales and grey or reddish sandstones, such as usually belong to the top of the slate series. The fossil remains of these situations are in consequence usually well exhibited on the surface of the beds, when, either naturally or by chemical or mechanical means, these surfaces can be cleared. (M. de Bonnard, in De la Beche's *Memoirs.*)

As on the one hand the irregularity and frequently nodular character of the limestones associated with slate, present a curious analogy to the older calcareous rocks of the gneiss and mica slate system, so the upper fossiliferous limestones of the slate, have often a special resemblance to the mountain limestone of the succeeding epoch, both in mineralogical character and organic remains. Judging from specimens only, and from an imperfect view of the English and Belgian series of strata, many Continental Geologists have been unable to discriminate between our transition and carboniferous limestones. Their conclusions on this point appear to have been sometimes influenced by the fact that trilobites and orthoceratites, as well as many encrinites, occur in both these rocks. Nevertheless they are really and permanently distinct, and their organic remains belong undoubtedly for the most part to very different species, and present altogether perfectly characteristic groups.

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Analogous to the newer carboniferous limestone,

but distinct from both in England, &c.

No English Geologist can for a moment hesitate to distinguish the fossils of the transition limestone of Malvern and Dudley, on the one hand, from those of Derbyshire and Flintshire on the other, nor should it be found difficult to separate in like manner the transition limestone of the Eifel from the carboniferous limestone of Namur. Both it is true are contiguous to slate, nor do they occur superimposed in one section; but the Namur limestone *lies on* the greywacke of the Ardennes, that of the Eifel *is enclosed in* it, and forms really a part of the slate system, as much as the limestone of Christiania, Cumbria, and Caermarthenshire. One principal reason of the confusion among Continental writers on the subject of these calcareous deposits in England, is the almost universal deficiency of the true carboniferous limestone beneath all the coal fields of continental Europe, except those of Mons, Namur, Liege, Dusseldorf, &c.

Finally, we must repeat the remark formerly made, that all the hard lines of distinction, which for convenience we draw across the scale of strata, may be locally exact and defined, but vanish on a more extended comparison of distant localities. The limestones of the slate system, generally, appear to connect the oldest calcareous rocks of the gneiss with the comparatively modern limestones of the coal measures. The greywacke slates which enclose them are also so much changed from the type of clay slate, as to assume very nearly the aspect of sandstones and shales, frequent in the carboniferous system; and thus, both by analogy of fossils and gradation of mineralogical characters, we are led without any startling chasm from the primary to the secondary strata.

The whole series of strata one system.

Moved by these considerations, some eminent English Geologists appear disposed to unite together the carboniferous system and the transition limestone group, and in some cases this may be a very convenient mode of arrangement; but tried by general comparisons it seems to offer no special advantage. For, by the same rule, we ought certainly to form but one class of rocks from the gneiss to the new red sandstone, since it can be most clearly proved that, in all this vast series, alternations and gradations prevail; but further, we should by rigorous extension of this mode of classification, have no division at all from the gneiss to the tertiary strata. In fact, it is already certain that the *whole series* of strata is a consequence of repeated actions of the same causes under modified circumstances, and the classification of the strata must be left in a great measure to the moderation and local convenience of the cultivators of Geology.

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There is little doubt that the line here drawn between the slate system and the carboniferous system may be easily recognised throughout Europe; and if in some cases the upper slates assume the aspect of sandstones and shales, and even contain traces of coal and plants, such as usually occur above, and the two sets of limestones thus divided resemble one another in certain mineral characters and organic remains, this ought not to surprise us, for it is a part of the general process of Nature.

Succession of primary strata.

To these remarks we shall only add a short connected view of the sequence of limestones in the whole primary period, according to our notions of their affinity, placing them in a descending order, with their alternating strata.

In the slate system.

- a. Arenaceous, calcareous, and argillaceous strata containing organic remains.
- 1. The limestone of Dudley, Ludlow, Herefordshire, full of organic remains.
- b. Die earth of Shropshire, containing organic remains and calcareous concretions. Arenaceous strata with organic remains and calcareous bands.
- 2. Llandilo limestone, associated with black shales, both containing trilobites and other fossils.
- c. Upper greywacke slates of Westmoreland, containing orbiculæ, orthocerata, and other organic remains.
- 3. Black slaty limestone of Westmoreland, with cyathophylla, millepora, orbicula, but hitherto no trilobites. Probably the limestone of Okehampton in Devonshire, and that of Bala in North Wales.
- d. Slate rocks.
- 4. Detached limestones of North Devon and North Wales.
- e. Slate rocks, rarely containing a few shells.

- f. Chloritic and micaceous schists of the Grampians.
- 5. Crystalline limestone of Loch Earn, Inverary, Dalmally, no organic remains.
- g. Chloritic and micaceous schists. Mica schists and gneiss.
- 6. Crystallized limestone of Glen Tilt, Strathfillan, Glen Croe, no organic remains.
- h. Gneiss, mica schist, &c.

General Conclusions concerning Primary Strata.

The general system of operations disclosed to us by an examination of the primary strata, presents the following leading points.

A general basis of igneous rocks.

I. The lowest rocks which we can trace, those upon which the vast accumulations of stratified rocks rest, are such as from all their characters appear to have been produced by igneous agency. These granitic, hypersthenic, &c. rocks are crystallized like the products of fire, composed of minerals like those observed to be generated by heat, and combined in a very similar manner. They show no action of water, either chemical or mechanical, nor contain the reliquiæ of living beings. The almost universal extent of these rocks, combined with the abundance of their disintegrated materials in the older strata, proves the great extent of the igneous agency developed in the earliest eras definable by Geologists.

Influence of heat on primary strata.

The same inference of a pervading and powerful developement of heat in those early periods, may be safely drawn from a consideration of the generally high degree of solidification among the primary strata, and their frequent though imperfect crystallization. There is little doubt, or rather the Geologist of sufficient observation considers it a matter of certainty, that the crystallization of primary limestone, the conglutination of gneiss and quartz rocks, and the rhomboidal fissures of slate, are due to the same cause as the conversion of chalk into such limestone, the induration and semifusion of sandstones, and the prismatizing of shale by the action of basalt, and by the heat of a furnace; and it is certain from various facts that these characters were acquired by the primary strata before the formation of any member of the secondary rocks.

Organic remains absent from the lowest primary strata;

II. Possibly this great and continuous heat beneath the ancient beds of the Ocean, may be admitted as a reason for the paucity of animal and vegetable life during the primary epoch. The fact, however, is that among the older of the primary strata the remains of plants and animals do not occur; and it is probable that the living wonders of Nature were not then in existence. It is, indeed, maintained that such remains would be wholly destroyed in the rocks by the operation of such a heat, and this opinion may be supported by many strong analogies. But as marine organic remains do occur, though rarely, in the midst of the slate group, (Snowdon, Tintagel,) and become numerous in and near the calcareous bands of the upper portion of that series, it appears safer to admit that the heat, or some other unknown condition of this early period, was unfavourable to organic existence in the sea. It seems almost demonstrated that at this period there was very little dry land raised to the surface of the Globe; for all the present Continents were certainly uplifted at subsequent and successive epochs, and therefore land plants could not be abundant.

become frequent in the upper.

III. But in proportion as the igneous agency found vent, in the same ratio as the mountains were uplifted, we find the organic reliquiæ of the sea and of the land imbedded in greater abundance. The plants indeed imbedded in coal strata associated with the upper part of the slate series (if really belonging to this system) are local deposits, and not at all to be compared in quantity with several accumulations of later date; but this is also in exact accordance with what is known of the relative extent of land at the different epochs.

Objections to this hypothesis considered.

It may be objected by those who see in the ancient effects of Nature nothing but the result of the present measure of natural operations, that two-thirds of the Globe are now covered by water, and that the depression of one large tract may have corresponded to the elevation of a smaller, and that remains of plants and animals may occur in the submerged portion of the crust of the Earth, of higher antiquity than any of our elevated strata. This *may be true;* and it may also be true, as some persons suppose, that stratified rocks full of organic remains occur beneath the granitic floor; but as neither of these hypotheses can be proved or even examined, they must remain as *mere speculation.*

But it may also be objected that the whole force of the argument as to the non-existence of organic beings in the earliest primary periods, goes upon the supposition that the primary strata of the same kind are all respectively of the same age, which demands the admission of almost universal formations; and this can never be allowed by those who adopt the existing measure of the effects of the natural agencies employed on the Globe, as a standard for all past periods of time.

No formation now in progress has more than a very limited area and a local character; but this very fact is decisive against the doctrine of the uniform rate and constant momentum of the several agencies of Nature; for no one can consider the wide strata of the chalk and oolite, and the still more expanded saliferous rocks, without being struck by the contrast between them and what we know of the varying bed of the actual seas. But

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these systems of strata, extensively as they are spread over the basin of Europe, appear, when contrasted with the primary strata, mere local deposits. If all the characteristic mountain ranges of the World show themselves composed of these strata, and furnish proof of the superior antiquity of these strata to those which surround the mountain slopes; and contain, though rarely, organic remains which do not exist among superior rocks; if, in short, these latter have the characters of nearly contemporaneous and comparatively recent origin, and the others of nearly coeval ancient date; why are we to reject the plain and obvious inferences from these facts, in order to embrace a narrow speculation, which, by fettering the mind to the results of observation on divided seas, low temperatures at the surface, and diminished heat within the Earth, refuses to consider the results of operations in the wide Ocean, brought on by almost universal chemical and mechanical agencies of heat?

General ground of argument.

In maintaining the *uniform character* of the natural terraqueous agencies, and the *constancy of their mode of action*, all Philosophers are agreed; but, as in every other problem submitted to investigation, experiment, or observation, the *conditions* are to be determined before the rate and measure of Geological results can be expressed on a scale of magnitude or number. In a Science founded on observation, these conditions cannot be known beforehand, they are the very objects of which we are in quest, and our only mode of approaching them is by analyzing the effects which have been produced by the known laws of Nature, operating under these, at first unknown, conditions. What is the object of an experimental investigation, in which first the law is given, and next the conditions are assumed, the result of their combined operation having been previously defined?

Greater effects of heat in the older Epochs.

A history of the successive revolutions in the state of the Globe, must indeed be founded on a survey of the chemical, mechanical, and vital phenomena now produced by the atmosphere, rivers, the sea, and volcanos; and all conclusions concerning the intensity, duration, and extent of igneous and aqueous agencies, in past Geological periods, must proceed upon an examination and estimate of these agencies in the existing periods; but the ratio of their effects at different periods is to be determined by evidence, not assumed by conjecture.

The results of examination of the organic remains in the several strata, and of the character and condition of these strata, according to their relative antiquity, leave no doubt of the vastly greater and more general influence which, in the older Geological periods, the *proper* heat of the Earth had upon all the operations of Nature in the sea and on the land, an influence far more equable as well as more intense than that exerted by the Solar rays, independent of the Seasons, and coextensive with the Globe.

Surely, then, under these peculiar conditions, the laws of Nature which are concerned in the operation, themselves invariable, must have operated on a greater scale, and perhaps with higher intensity, than that which now characterises their effects.

All the results depending directly on the *quantity* of communicated heat,—as, for instance, most of the phenomena connected with the decomposition, reconstruction,—and consolidation of rocks, must have been vastly increased in amount, and proportioned in extent to the universal diffusion of heat; while the arrangements of organic life, which we know to be *adjusted to a certain limited range* of temperature, must have been proportionately affected. Until the mean temperature of the sea was reduced to a certain standard, the Physical conditions to which organic life is restricted on our Globe were not established; but during these periods the inorganic forces of Nature must have been especially active, and on a very great scale. Hence the vast thickness, the great degree of consolidation, the crystalline character, the almost universal extent of the primary strata; hence the rarity of organic remains, until, by the accumulation of considerable thicknesses of nonconducting earthy materials upon the bed of the Ocean, the communication of heat from the interior of the Globe was retarded, so as to be counterbalanced by that constant radiation from its surface, which is one of the conditions whereto the organization of plants and animals is adjusted.

Disturbances of the Primary Strata.

During the accumulation of the slates.

Though during the accumulation of the slates beneath the waters of the sea, considerable tranquillity and a repetition of similar circumstances prevailed, as may be inferred from the correspondence of the stratification, the rarity of conglomerates, and the general agreement of the organic remains at different points over immense surfaces, yet some remarkable exceptions occur, enough to show that the subterranean forces to which our Continents owe their present forms and elevations, were not wholly inactive. In the Cumbrian mountains, especially, we may clearly perceive the effects of some considerable local disturbance in the conglomerate rock of St. John's Vale, Barrow, and Grasmere; and the singular admixture and blending of porphyries, amygdaloids, and greenstones, with the ordinary argillaceous slates, proves evidently a great and continued developement of igneous agency *during* the deposition of the middle slate rocks of the lakes. Similar effects appear to have happened in Snowdonia, and some remarkable cases of extensive disturbance have been ascertained along the Eastward border of the Welsh slate system.

After the deposit of slates.

But immediately after the completion of the slate deposit, and before the commencement of the carboniferous system, a much more general and more violent succession of dislocations happened. At this period nearly all the primary ranges of the British Islands received their most remarkable features; and it is deserving of notice that some of the most important of the lines of elevation and depression then produced by subterranean expansion,—for instance, the Grampians, the valley of the Caledonian canal, the Lammermuir hills, and the prolongation of these ranges in Ireland, the Cumbrian, Snowdonian, and Cornish chains, and the hills of the Isle of Man,—run in the same direction from North-East to South West. This is the most striking example which the British Islands afford in favour of Elie de Beaumont's hypothesis of the accordance between the direction of the axis of a mountain group and the date of its elevation. Elie de Beaumont notices as belonging to the same period as the elevation of the Cumbrian and Cornish chains, the system of the Hundsruck in Westphalia, the country of the Eifel, and the mountains of Nassau, in all of which the principal ranges are North-East by East, and South-West by West. Other examples will hereafter be mentioned which seem irreconcilable to his views; in the mean time we may state that the contemporaneous elevation of the greywacke systems

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of the South of Ireland and Devonshire ranges East and West. Elie de Beaumont, indeed, distinguishes between the dates of these Eastern and Western lines of elevation, and those previously traced in a North-Eastern and South-Western direction, and refers them to a later period. The North-Eastern lines are considered to have been caused *during* the transition (slate) period, and the Eastern and Western, *immediately after* that period. This requires further examination. Professor Sedgwick attributes to the Cumbrian slates one great elevation anterior to the carboniferous system, and we may safely adopt this as a general view, though there appears good reason to doubt whether all the various Plutonic rocks mixed in so singular a manner among the conglomerate slates of Cumbria, were injected at one period.

Influence on the mean direction of strata.

In consequence of these elevations, the strata of slate thrown up towards a central ridge of Plutonic rocks exhibit amidst many irregularities prevailing dips towards the South-East and North-West, and have thus considerably influenced the mean bearing of all the subsequent deposits of British strata in which a very general tendency to the North-Eastern and South-Western direction has been for a long time observed.

Plutonic rocks are often visible along the axis of these ancient elevations. The Cumbrian chain encloses a line of nuclei of granite, syenite, and hypersthene rocks, besides various porphyries and greenstones in dykes, and overlying plateaux, of which the age is less certainly indicated. These have evidently been injected in a melted state into fissures produced during the general movement of the stony masses; but there is rarely any proof derived from veins, or from the appearances at the points of their contact with other rocks, that the central granitic masses were uplifted in a melted state. But in Cornwall, in the North of Ireland, and still more generally in Scotland, the granitic rocks were evidently in a state of fusion, since the deposit of the slates, and, accordingly, these latter rocks, and the various strata associated with them, are often penetrated by veins of granite, and materially altered at the surfaces of contact. Have the fissures occasioned by these intestine subterranean movements furnished the cavities which have since, by injection, sublimation, and segregation, been filled by various metallic and mineral substances?

Mineral veins

These *mineral veins* are, upon the whole, more numerous in the primary strata than in any of the secondary rocks; and the generally admitted fact that they are not all of the same age in the same mining country, may lead us to suppose that their production was not confined even to one great epoch in Geology, but was repeated at intervals during the whole period of the formation of the strata.

Table of the Organic Remains of the Slate System.

The mark * signifies that the species to which it is attached occurs in the carboniferous system also.

PLANTS.

Family.	Name.	Foreign Localities.
Algæ	Fucoides antiquus, Bgt.	Christiania.
	serra, Bgt.	Quebec.
	dentatus, Bgt.	Ditto.
	circinatus, Bgt.	Base of Kinnekülle, Sweden.
Equisetaceæ	Calamites radiatus, Bgt.	Bitschweiler. (Haut Rhin)
	Voltzii, Bgt.	Zundsweiher. (Baden.)
Filices	*Sphenopteris dissecta, Bgt.	Berghaupten. (Baden.)
	Cyclopteris flabellata, Bgt.	Ditto.
	*Pecopteris aspira, Bgt.	Ditto.
	*Sigillaria tessellata, Bgt.	Ditto.
	Voltzii, Bgt.	Zundsweiher.
Lycopodiaceæ	Lepidodendron. (several species.)	Berghaupten, Bitschweiler.
	*Stigmaria ficoides, Bgt.	Bitschweiler.
Class uncertain	Asterophyllites pygmæa, Bgt.	Berghaupten.
	Fossil plants generally	Near Namur.

This list, which is taken almost wholly from M. A. Brongniart's *Prodrome de l'Histoire des Végétaux Fossiles*, will be found remarkably analogous to the more extended catalogue of the plants of the carboniferous system of strata. The fourteen or more species of plants here recorded, belong to genera which occur likewise in the carboniferous strata above, and four of the species, marked by an asterisk, are found again in these rocks. Three of the four occur at Berghaupten, in coal measures which may be of the true carboniferous epoch. All the genera are, probably, extinct, though with respect to the filices this is difficult to prove, on account of the almost total want of fructification in the fossils, and their generally fragmentary state. Four species are marine, two or three probably belonged to marshes, and seven or eight or more to drier situations. The marine plants are mostly found in limestone. The number of species is too small to furnish, alone, any general inferences either as to the prevalent character of the Flora, or the climate of this period; yet taken in connection with the carboniferous system, they appear to warrant a belief that vascular cryptogamic plants were in possession of the land, that this was very limited in extent, and that the climate was hot.

Organic Remains of the Slate System.

POLYPARIA.

Family.	Name.	British Localities.	Foreign Localities.
Fibrosa	Achilleum cariosum		Groningen. (loose specimen.)
	Manon cribrosum		Eifel.
	Scyphia conoidea		Ditto.
	turbinata		Ditto.
	clathrata		Ditto
	costata		Ditto.
	Tragos acetabulum		Ditto.
Corticifera	Gorgonia antiqua		Eifel, Ural.

Family.	Name.	British Localities.	Foreign Localities.
Corticifera	Gorgonia infundibuliformis		Wipperfürth, Eifel, Ural.
Cellulifera	Stromatopora concentrica		Eifel.
	polymorpha		Ditto, Bensberg.
	Cellepora antiqua	Glouc. Heref.	Ditto.
	Retepora prisca		Ditto.
	antiqua		Ditto.
	undetermined	Ditto.	
	Millepora, several species		*Gottland.
	Coscinopora placenta		Eifel.
	Flustra lanceolata		Gottland.
	Ceriopora affinis	Dudley	Eifel.
	punctata	Ditto	Ditto.
	granulosa	Ditto	Ditto.
	oculata	Ditto	Ditto.
	disticha	Ditto	Ditto.
	favosa	Ditto	Ditto.
	Glauconome disticha	Ditto	Ditto.
	Calamopora, G. } Favosites, Lam. } Bromellii, Mün.		Nehou. (Manche.)
	truncata, Raf.		Kentucky.
	Kentuckensis, Raf.		Ditto.
	boletus, Mün.		Christiania.
	alveolaris		Eifel, Groningen.
	favosa		Lake Huron.
	Gottlandica	Douglas near Dublin	Gerolstein, Lake Huron, Catskill Mountains.
	basaltica		Lake Erie, Eifel, Gottland.
	infundibulifera		Eifel, Bensberg.
	*polymorpha		Ditto, Ditto, Pfaffrath.
	spongites	Shropshire, Dudley	Eifel, Sweden.
	fibrosa		Niagara, Kentucky, Eifel, Bensberg.
	cervicornis		Gottland.
	Aulopora alecto, Lam. serpens		Eifel, Bensberg, Gottland, Christiania.
	tubæformis		Eifel.
	spicata		Ditto, Bensberg.
	glomerata		Bensberg.
	elegans		Ditto.
	sarmentacea		Eifel.
	Catenipora escharoides, Lam.	Shropshire, Herefordshire, &c.	Ditto, Christiania, Gottland, Lake Huron, Moscow.
	labyrinthica		Groningen, Drummond Island.
	tubulosa, Lam.		Christiania.
	Syringopora verticillata		Lake Huron.
	ramulosa		Limburg.
	reticulata		Ditto.
	cæspitosa		Pfaffrath near Coln.
	filiformis		Groningen.
	undetermined	Glouc. Shrop. &c.	
Lamellifera	Agaricia lobata		Eifel.
	Swinderniana		Groningen.
	Lithodendron cæspitosum	Glouc. Heref., &c.	Bensberg.
	Anthophyllum denticulatum		Niagara.
	bicostatum		Eifel.
	Cyathophyllum plicatum		Kentucky.
	dianthus		Eifel.
	radicans		Ditto.
	marginatum		Bensberg.
	explanatum		Ditto.
	turbinatum		
	hypocrateriforme		Eifel.
	ceratites		Ditto, Bensberg.
	flexuosum		Eifel.
	vermiculare		Ditto.
	secundum		Ditto.
	lamellosum		Ditto.
	placentiforme		Ditto.
	plicatum		Sweden.
	quadrigeminum		Eifel, Bensberg.
	cæspitosum		Eifel.
	hexagonum		Ditto, Bensberg.
	helianthoides		Eifel, Lake Huron.
	Strombodes pentagonus		Drummond Island, Lake Huron.
	Astræa ananas		Gottland.
	porosa	Glouc. Heref.	Eifel, Bensberg.
	Columnaria alveolata		Seneca Sea. (New York.)
	Sarcinula punctata, Park.	Gloucestershire.	
	organum		Gottland.
	angularis, Fl.	Dudley.	
	Mastrema pentagona, Raf.		Kentucky.
	Pleurodictyum problematicum		Nassau, Hundsruck.
	Hydnophora	Shropshire.	
	*Amplexus coralloides, Sow. } Cyathoph. flexuosum? Goldf. }		Mont Chatou, near Coutances, Catskill Mountains.

In the above list the specific names are chiefly adopted from Goldfuss.

The great number and variety of the species of polyparia in strata so near in position to those which contain no traces of living Beings, is remarkable, and sets in a strong light the error of those who suppose the paucity or deficiency of organic remains in the lower strata is owing merely to their antiquity; while at the same time the almost exclusive limitation of these remains to the calcareous beds of the slate system shows that the true cause both of their rarity in the one case, and their plenty in the other, must be sought in the condition of the sea at the different periods. It is especially worthy of notice, that though nearly all the species are peculiar to the slate system, most of the genera are repeated in the carboniferous limestone above, and several exist in the present sea, as madrepora, astræa, cellepora, retepora, gorgonia.—Types of all the most remarkable living tribes of polyparia are preserved in these ancient repositories; the lamelliferæ bear the same large proportion to the other corals as now obtains in hot seas, and it is evident that the general arrangements of Nature with respect to the life of marine animals were of the same kind as at present.

With respect to the Geographical distribution of the species our Catalogues and our Collections appear to present a remarkable contrast; for while the former seem to show that a very few species only have been recognised at more than one locality, the general impression derived from a view of the latter is exactly the reverse. The systematist is perhaps too easily led to multiply distinctions without necessity, while the eye of the ordinary observer is more easily imposed on by the analogy of kindred forms. At all events, it is certain that the zoophites of this limestone are eminently characteristic of it, and some of the genera may almost be taken to represent it: such are favosites, catenipora, amplexus; and yet these all occur (less abundantly) in the carboniferous limestone.

Organic Remains of the Slate System.

RADIARIA.

Family.	Name.	Rock.	British Localities.	Foreign Localities.
Crinoidea	Pentremites florealis, G.	Calcareous		Mississippi.
	Caryocrinus			North America.
	Eugeniacrinus mespiliformis, G.	Ditto		Eifel.
	Pentacrinus priscus, G.	Ditto		Ditto.
	Platycrinus ventricosus, G.	Ditto		Ditto.
	*pentangularis	Ditto	Dudley, Din vawr.	
	Cyathocrinus tuberculatus	Ditto	Dudley.	
	*rugosus	Ditto	Shropshire	Oeland, Dalecarlia, Eifel.
	geometricus, G.	Ditto		Eifel.
	pinnatus, G.			Ditto.
	pentagonus, G.			Groningen.
	Actinocrinus moniliformis	Ditto	Dudley.	
	*30-dactylus			Eifel.
	lævis			Ditto.
	cingulatus, G			Ditto.
	muricatus, G.			Ditto.
	nodulosus, G			Ditto.
	moniliferus, G			Ditto.
	Melocrinus hieroglyphicus, G.			Ditto
	gibbosus, G.			Ditto.
	*Rhodocrinus verus		Dudley	Ditto.
	gyratus, G.			Ditto.
	5-partitus, G.			Ditto.
	canaliculatus, G			Ditto.
	crenatus, G.			Ditto.
	Cupressocrinus crassus, G.			Ditto.
	gracilis, G.			Ditto.
	tesseratus, G.			Ditto.
	Eucalyptocrinus rosaceus, G.			Ditto.
	Echinosphærites pomum, W.			Oeland, Kinnekülle, near St. Petersburgh.
	aurantium, W.			Mösseburg, Westrogothia.
	granatum, W			Oeland, Dalecarlia.
	Wahlenbergii, E.			Gulf of Christiania.
	Encrinites Gothlandicus, W.			Gottland.

In the preceding list of radiaria, all the species named by other authors than Miller, have the initials of those authors, as Goldfuss, Wahlenberg, Esmark. The thirty-four species here collected have all vanished from the present ranks of Creation, but we find at least four repeated in the carboniferous limestone. Six of the thirteen genera are also continued into that limestone, and two, (eugeniacrinites and pentacrinites,) the latter of which is unknown in carboniferous limestone, are rather plentiful in the oolitic rocks. The crinoidea of the slate system are almost exclusively found in limestone, and only locally distributed in that rock. No true echinida or stellerida have yet been described from these ancient rocks.

Organic Remains of the Slate System.

CONCHIFERA.

Family.	Name.	British Localities.	Foreign Localities.
Plagymyona	Trigonia sulcata, G.		Lindlar.
	concentrica, G.		Ditto.
	undetermined, Ph.	Near Kirby Lonsdale.	
	Cardium costellatum, Mün.		Elbersreuth, Prague.

Family.	Name.	British Localities.	Foreign Localities.
Plagymyona	Cardium hybridum, M.		Elbersreuth.
	lineare, M.		Ditto.
	priscum, M.		Ditto, Prague.
	striatum, M.		Elbersreuth.
	*alæforme, Sow.	Plymouth, Newton Bushel	Eifel.
	costellatum, M.		Elbersreuth.
	gracile, M.		Ditto.
	plicatum, M.		Ditto.
	tripartitum, M.		Ditto.
	fasciculatum, G.		Kemmenau. (Ems.)
	marginatum, G.		Ditto.
	carpomorphum, Dalm.		Sweden.
	Isocardia Humboldtii, Hæn.		Wissenbach, near Dillenburg.
	Venericardium retrostriatum, v. Buch.		Martenberg (Waldeck.)
	Crassatella obsoleta, G.		Wipperfürth.
	Lucina *proacia, G.		Eifel, Bensberg.
	*lineata, G.		Ditto.
	rugosa, G.		Ditto.
	*cincta, G.		Ditto.
	Tellina obliqua, G.		Kemmenau.
	Cyprina minuta		Eifel.
	Corbula zonaria		Ditto.
	Cytherea Okeni, M.		Reguitzlosau.
	inflata, M.		Ditto.
	Hisingeri, M.		Ditto.
	elongata, M.		Ditto.
	bilobata M.		Ditto.
	subcylindrica, M.		Ditto.
	intermedia, M.		Ditto.
	Sanguinolaria gibbosa, S.		Altenahr.
	undulata ? S.		Siebengebirge.
	concentrica, G.		Eifel.
	lamellosa, G.		Ditto.
	dorsata, G.		Ditto, Altenahr.
	truncata, G.		Ditto.
	phaseolina, G.		Ditto.
	solenoides, G.		Siebengebirge, Altenahr.
	Pholadomya radiata, G.		Eifel.
	Solen *pelagicus, G.		Ditto.
	vetustus, G.		Ditto.
	*Megalodon cucullatum, S.	Newton Bushel	Pfaffrath.
	Modiola Goldfussii, Hæn.		Eifel.
	antiqua, G.		Ems.
	Gothlandica, His.		Gottland.
	Mytilus vetustus, G.		Dillenburg, Upper Canada.
	Arca prisca, G.		Kloster Bruck. (Sollingen.)
	Nucula antiqua, G.		Harz, Ems.
	*subnoides, G.		Ditto.
	fornicata, G.		Olpe.
	securiformis, G.		Ems.
	pinguis, G.		Ditto.
Mesomyona	Aptychus antiquus, G.		Geistlicher Berg. (Herborn.)
	lævigatus, G.		Eifel.
	Avicula obsoleta, G.		Abendtheuer. (Hundsruck.)
	lepida, G.		Geistlicher Berg.
	Pterinea ventricosa, G.		Kemmenau, Altenahr.
	costata, G.		Ems, Siebengebirge.
	lineata, G.		Kemmenau.
	lamellosa, G.		Siegen, Harz.
	reticulata, G.		Iserlohn.
	radiata, G.		Ditto, Eifel.
	carinata, G.		Pfaffendorf, (Coblenz,) Oneida, N. A.
	plana, G.		Kemmenau.
	trigona, G.		Ditto.
	Posidonia Becheri, Bron.		Geistlicher Berg, Ründeroth, Frankenberg, Werden.
	longitudinalis, B.		Edderbringhausen. (Frankenberg.)
	Pecten grandævus, G.		Geistlicher Berg.
	oceani, G.		Harz.
	Neptuni, G.		Eifel.
	primigenius, G.		Wissenbach.
	Münsteri		Ditto.
	undetermined, Phil.	Near Kirby Lonsdale.	
	Gryphæa undetermined, P.	Ditto.	
	Plagiostoma? or pterinea? undetermined, P.	Ditto.	
Brachiopoda	Producta, S. / Leptæna, Dal. } depressa, S.	Dudley, Plymouth	Eifel, Gottland, Lithuania.
	*scotica, S.		Eifel.
	*hemisphærica, S.		Ditto, Catskill Mountains, Albany, Lexington.
	rostrata, S.		Bensberg.
	*sulcata, S.		Catskill Mountains.
	anomala, S.	Plymouth	

Family.	Name.	British Localities.	Foreign Localities.
Brachiopoda ...	Producta, Sow. / Leptæna, Dal. } sarciaulata, G.		Eifel, Catskill Mountains.
	lata, v. Buch.		Sweden ? (found at Güstrow.)
	euglypha, D.		Eifel, Gottland.
	rugosa, D.		Ditto, Ditto, Catskill Mountains, Oeland, Schonen, Dalecarlia.
	transversalis D.		Gottland, Oeland, Schonen, Dalecarlia, East and West Gottland.
	deflexa, D.		East Gottland.
	echinata, D / aculeata ? S.		Gottland.
	convoluta, G.		Eifel.
	furcata, G.		Ditto.
	capillata, G.		Ditto.
	striata, G.		Coblenz.
	pectinata, G.		Eifel, Coblenz, Kaiserstuhl.
	minuta, G.		Eifel.
	*scabricula, S.		Ditto.
	Orthis, pecten, D.		Ditto, Borenshult, East and West Gottland, Catskill Mountains, Wipperfürth.
	*striatella, D.		Gottland, Lithuania.
	zonata, D.		Borenshult.
	callactes, D.		Husbyfjoel, Ulanda, West Gottland.
	calligrama, D.		Skarpåsen, East Gottland, Trentonfalls.
	testudinaria, D.		Borenshult, Blankenheim, Trentonfalls.
	basalis, D.		Gottland.
	elegantula, D.		Ditto.
	demissa, D.		Oeland.
	novem radiata, D.		Ditto.
	radiata, D.		Eifel.
	costata, D.		Kentucky.
	rugosa, Raf.		Lake Huron.
	granulosa, G.		Catskill Mountains.
	fasciculata, G.		Eifel.
	undulata, G.		Albany.
	nodosa, G.		Eifel.
	Delthyris, D. / Spirifera, S. } *minima, S.		Blankenheim.
	*attenuata, S.		Eifel, Coblenz.
	*obtusa, S.	Plymouth.	
	*rotundata, S.	Newton Bushel.	
	*lineata, S.	Dudley.	
	distans, S.	Plymouth.	
	*reticulata, S.	Ditto.	
	pentagona, S.	Ditto.	
	* cuspidata, S. / elevata, D.	Ditto	Eifel, Bensberg, Coblenz.
	*glabra, S	Ditto.	
	alata, S.		Coblenz.
	*ambigua, S.		Blankenheim.
	*decurrens, S.	Newton Bushel.	
	*distans, S.	Plymouth.	
	*octoplicata, S. / crispa, D.	Ditto	Gottland, Eifel.
	exporrecta, W.		Gottland.
	trapezoidalis, His.		Ditto, Pfaffrath, Eifel.
	cyrtana, D.		Gottland, Eifel, Bensberg.
	subsulcata, D.		Oeland.
	ptychodos, D.		Gottland.
	cardiospermiformis	Dudley	Ditto.
	pusio, H.		Ditto.
	psittacea, W.		Dalecarlia.
	jugata, W.		Ditto.
	*lævicosta, G.		Bensberg, Eifel, Coblenz.
	microptera, G.	Glouc. Heref.	Eifel, Alleghany, Siebengebirge, &c.
	triangularis, S. / compressa, G.		Bensberg.
	heteroclyta, G.		Eifel.
	macroptera, G.		Catskill, Coblenz, Ems, &c.
	leptoptera, G.		Eifel, Lindlar.
	pachyoptera, G.		Hudson. (New York.)
	canalifera, G.		Bensberg.
	canaliculata, G.		Ditto.
	*striatula, G.		Ditto, Eifel, Christiania, Trentonfalls, &c.
	Pentamerus Knightii et / Aylesfordii, S.	Yeo Edge, Downton, &c.	Eifel.
	lævis, S.	Near Ludlow.	
	Gypidia conchidium, D.		Gottland, Lithuania.
	gryphoides, G.		Pfaffrath.
	lævis, G.		Ditto.
	Strygocephalus Burtini, Defr.		Bensberg, Eifel.
	striatus, G.		Eifel.

Family.	Name.	British Localities.	Foreign Localities.
Brachiopoda	Atrypa, Dal. / Terebratula, Sow. } affinis, S.	Dudley, Plymouth, Ledbury.	Eifel, Bensberg, West Gottland, &c.
	aspera, Schl.		Eifel, Bensberg, Gottland, Christiania.
	canaliculata, D.		Oeland, Lithuania.
	galeata, D.		Eifel, Gottland.
	nucella, D.		East Gottland.
	crassirostris, D.		West Gottland.
	lenticularis, D.		Oeland, West Gottland, Andrarum.
	cassidea, D.		Gottland.
	dorsata, His.		Orland.
	prunum, D.		Gottland.
	tumida, D.		Ditto.
	tumidula, His.		Ditto.
	micula, D.		Schonen.
	nitida, G.		Lake Simcoe
	Terebratula *lateralis, S.		Eifel.
	*crumena, S.		Ditto, Lake Huron, Lindlar.
	*pugnus, S.	Plymouth	Eifel.
	*Mantiæ, S.		Ems.
	*acuminata, S.		Eifel.
	porrecta, S.	Newton Bushel.	
	*platyloba, S.	Plymouth.	
	Hennahiana, S.	Ditto.	
	gigantea, S.	Ditto.	
	rotundata, S.	Ditto.	
	lachryma, S.	Ditto.	
	triloba, G.		Eifel.
	canaliculata, G.		Ditto.
	quinquelatera, G.		Ditto.
	dichotoma, G.		Ditto.
	pentagona, G.		Ditto.
	Wahlenbergii, G.		Ditto.
	subglobosa, G.		Ditto.
	bifida, G.		Ditto.
	clavata, G.		Ditto.
	amygdala, G.		Ditto.
	concentrica, Brown.		Ditto.
	heterotypa, Brown.		Ditto.
	*plicatella, D.	Plymouth	Borenshult, Husbyfjoel, East Gottland.
	lacunosa, Wahl.	Herefordshire	Porsgrund, (Norway.)
	*diodonta, D.		Eifel, Gottland.
	cuneata, D.		Gottland.
	bidentata, His.		Ditto, Djupriken.
	marginalis, D.		Klintoberg, Gottland.
	didyma, D.		Gottland.
	Calceola sandalina, Lam.		Eifel.
	Crania prisca, Hæn.		Ratingen (in greywacke.)
	Orbicula concentrica, v. Buch.		Martenberg (Waldeck.)
	rugata, Murchison	Herefordshire, Kirby Lonsdale	
	Lingula undetermined, Murchison	Herefordshire.	

All the leading divisions of living conchifera are recognised in the shells of the slate system, but there is a singular contrast between the present and the ancient systems, as to the relative proportions of these divisions. A short tabular comparison will render this very evident.

Of 100 conchifera now living 80 are plagymyonous; 18 mesomyonous; 2 brachiopodous: belonging to the slate system, 27 are plagymyonous; 11 mesomyonous; 62 brachiopodous. Of 78 species belonging to plagymyona and mesomyona, 3 are repeated in carboniferous limestone, and 10 of the 11 genera which include them are continued through a long range of secondary rocks.

Nearly all the genera (as yet imperfectly understood) of the brachiopodous bivalves are also found abundantly in carboniferous limestone. Of all these, terebratula is the only one now living, and it is very correct to say that the forms of these "primary" species recede much more from the living terebratulæ than do those of the less ancient secondary strata. The muscular and ligamental structure of these animals, could it be well made out, would surely afford very curious results. The shells are most frequent in the limestones, but not by any means confined to them. Of 129 species included in the preceding lists, 17 occur also in the carboniferous limestone, and for the most part abundantly. The localities in which these shells are stated to occur in transition limestone are, Plymouth, Newton Bushel, and Torquay in Devonshire, 10 species; Isle of Man, 2 species; Herborn, Blankenheim, and the Catskill Mountains. We must leave it to future observers to say, whether any other such coincidences occur at these and other places, and whether it is quite certain that the limestones of Devonshire really belong to the transition series, a point on which we cannot avoid feeling some doubt.

The following conchifera, chiefly collected by Mr. Weaver from limestone in the South of Ireland, are referred by M. De la Beche to the transition limestone. We have found in comparing this list with that of fossils indubitably belonging to the carboniferous epoch, so extraordinary an identity, and on the other hand, when compared to characteristic fossils of transition limestone obtained from Countries in which its Geological relations are certain, so marked a discordance, that we must for the present keep the fossils from the South of Ireland separate.

Isocardia *oblonga.
Spirifera *cuspidata.
*glabra.

Spirifera *obtusa.
*striata.
*pinguis.
reticulata.
Terebratula *crumena.
*cordiformis.
*pugnus.
*rostrata.
†affinis.
*lævigata, Sch.
elongata, Sch.
*acuminata.
*lateralis.
Terebratula *reniformis.
Producta *Scotica.
*Martini.
*concinna.
*lobata.
*punctata.
*fimbriata.
†depressa.
anomala.

In the above list the species marked * are common fossils in the carboniferous limestone, those marked † are usual in transition limestone.

Gasteropoda.

Family.	Name.	British Localities.	Foreign Localities.
Holostomata	Patella ? conica, W.		Kinnekülle.
	pennicostes, W.		Ulanda.
	concentrica, W.		Mösseberg.
	Neptuni, G.		Eifel, Olpe.
	primigena, G.		Pfaffrath.
	Pileopsis *vetusta, S.	Plymouth, near Ludlow.	
	prisca, G.		Eifel.
	compressa, G.		Ditto.
	Sigaretus ? rugosus, G.		Ditto.
	Nerita subcostata, G.		Pfaffrath, Ems.
	* spirata, S.	Ditto.	
	Delphinula ? æquilatera, W.		Gottland, West Gottland.
	obvallata, W.		Dalecarlia, Oeland.
	cornu arietis, W.		Gottland.
	alata, W.		Ditto.
	subculcata, His.		Ditto.
	Euomphalus angulosus, S.	Benthall Edge.	
	discors, S.	Shropshire, Dudley.	
	* nodosus ? S.		Eifel, Bensberg.
	rugosus, S.	Colebrook Dale.	
	* catillus, S.		Lake Erie.
	funatus, S.	Shropshire, Ledbury, Dudley.	
	spinosus, G.		Bensberg.
	* lævis, G.		Ditto.
	radiatus, G.		Eifel.
	striatus, G.		Ditto.
	articulatus, G.		Ditto.
	depressus, G.		Ditto.
	Delphinuloides, G.		Bensberg, Eifel, Dillenberg.
	trigonalis, G.		Bensberg, Eifel.
	carinatus, G.		Ditto, Ditto.
	angulatus, W.		Gottland.
	substriatus, His.		Ditto.
	centrifugus, W.		Dalecarlia, Wikarby, Gottland.
	costatus, His.		Gottland.
	Cirrus * acutus, S.	Plymouth, Tutworth.	
	exaltatus, G.		Eifel.
	ellipticus, His.		Dalecarlia.
	Turbo * tiara, S.	Plymouth.	
	bicarinatus, W.		Wikarby, Dalecarlia, Borenshult, &c.
	armatus, G.		Eifel.
	nodosus, G.		Ditto.
	Pleurotomaria striata, S.		Ems.
	cirriformis, S.	Ditto.	
	Turbo cælatus, G.		Eifel.
	porcatus, G.		Bensberg.
	Rotella helicinæformis, G.		Pfaffrath, Eifel.
	Turritella cingulata, His.		Gottland.
	bilineata, G.		Bensberg, Pfaffrath, Eifel.
	coronata, G.		Pfaffrath.
	abbreviata, S.	Newton Bushel.	
	spinosa, S.	Ditto, Plymouth	Bensberg.
	striata, G.		Eifel.
	obsoleta, G.		Ditto.
	Phasianella ventricosa, G.		Ditto.
	buccinoides, G.		Ditto.
	fusiformis, G.		Ditto.
Solenostomata	Murex ? harpula, L.	Plymouth, Newton Bushel.	
	Buccinum *acutum, S.	Plymouth	Bensberg, Pfaffrath.
	imbricatum, S.	Plymouth, Newton Bushel	Bensberg.
	breve, S.	Newton Bushel.	
	arcuatum, Schl.		Ditto.
	Terebra *Hennahiana	Plymouth.	

CEPHALOPODA.

Family.	Name.	British Localities.	Foreign Localities.
Monothalamia.	Bellerophon *tenuifascia, S.	Newton Bushel.	
	*cornu arietis, S.		Catskill Mountains.
	*apertus, S.		Eifel, Plattsburg.
	*costatus, S.	Plymouth	Lithuania.
	undulatus, G.		Blankenheim.
	striatus, G.		Ditto, Bensberg.
	Hupschii, Def.		Pfaffrath.
	Caucasicus, Fischer.		Moscow.
	cicatrisatus, F.		Ditto.
	helicoides, F.		Ditto.
	nodulosus, G.		Bensberg, Harz.
Polythalamia.	Conularia *quadrisulcata, S.	Gloucestershire	Canada.
	*teres		Lochport, Eifel.
	pyramidata, Hœn.		May near Caen.
	Orthoceras cinctum, S.	Herefordshire.	
	circulare, S.	Dudley, Herefords. Plymouth.	
	annulatum, S.	Salop	Eifel.
	striatum, S.		Malmoë, Christiania, New York.
	giganteum, S.		Elbersreuth, Eifel.
	undulatum, S.		Tzarkos-zelo. (St. Petersburg.)
	acuarium, M.		Elbersreuth.
	regulare, Sch.		Oeland.
	striato punctatum, M.		Elbersreuth.
	cingulatum, M.		Ditto.
	torquatum, M.		Ditto.
	*Steinhaueri, S.		Ditto.
	carinatum, M.		Ditto.
	lineare, M.		Ditto.
	irregulare, M.		Ditto.
	commune, W.		In Sweden common.
	duplex, W.		Kinnekulle, New York.
	trochleare, Dal.		Sollerøe (Dalecarlia.)
	centrale, D.		Ditto.
	turbinatum, D.		Oeland.
	gracile, Blum.		Geistlicher Berg, Wissenbach.
	rectum, Bosc.		Kuchel. (Prague.)
	excentricum, G.		Bensberg, Gladbach.
	nodulosum, G.		Eifel.
	imbricatum, W.		Gottland.
	angulatum, W.		Ditto.
	lineatum, His.		Ditto.
	striolatum, V. Meyer		Geistlicher Berg, Frankenberg.
	inflatum, G.		Eifel, Gottland, Lake Huron.
	Cyrtoceras semilunare, G.		Bensberg.
	depressum, G.		Eifel.
	compressum, G.		Ditto.
	ornatum, G.		Bensberg.
	annulatum, G.		Eifel.
	lineatum, G.		Ditto.
Polythalmia.	Spirula compressa, G.		Eibach. (Dillenburg.)
	nodosa, G.		Eifel.
	costata, G.		Ditto.
	annulata, G.		Ditto.
	carinata, G.		Ditto.
	dorsata, G.		Ditto.
	constricta, G.		Montmorency Falls.
	Nautilus divisus, M.		Geistlicher Berg.
	intermedius, M.		Hof Schleitz.
	ovatus, S.		Ditto.
	Lituites perfectus, W.		Mösseberg, Reval.
	imperfectus, W.		Jungby. (Sweden.)
	undescribed	Herefordshire, Yorkshire.	
	Ammonites (Goniatites, v. H.)		
	A. Gon. expansus, v. B.		Geistlicher Berg.
	evexus, v. B.		Eifel.
	Noeggerathi, G.		Ditto, Wissenbach.
	subnautilinus, Sch.		Wissenbach.
	primordialis, Sch.		Harz, Goslar.
	Becheri, G.		Dillenburg.
	priscus, G.		Ditto.
	antiquus, G.		Ditto.
	Hœninghausii, v. B.		Bensberg.
	Münsteri, v. B.		Elbersreuth.
	simplex, v. B.		Goslar.
	multiseptatus, v. B.		Eifel.
	inæquistriatus, M.		Elbersreuth.
	semistriatus		Ditto.
	speciosus, M.		Ditto.
	retrorsus, v. B.		Martenberg. (Waldeck.)
	Dalmanni, His.		Gottland.

The mollusca of the slate system range themselves under 16 gasteropodous and 8 cephalopodous genera. There are stated to be 64 species of the former and 79 of the latter. The gasteropodous genera are mostly thought to be identical with those now in existence; excepting nautilus, all the cephalopoda are extinct generically. All the species are extinct, though N. caurena, Lam., is (we suppose by mistake) quoted as found in America.

The ammonites of this system are of the same generic types as those in the carboniferous limestone, with waved or angulated, but not foliaceous sutures.

From the South of Ireland we have,

Melania constricta.*
Pileopsis vetusta.*
Nerita.
Cirrus acutus.*
Euomphalus catillus.*
Pleuromaria cirriformis.
Bellerophon tenuifascia.*
ovatus.
Orthoceras striatum.
paradoxicum.
Nautilus globatus.*
Nautilus multicarinatus.*
cariniferus.*
(Ellipsolithes) funatus.
compressus.
ovatus.
Ammonites.

In which list the asterisks show analogy to the carboniferous limestone, while perhaps not a single fossil is characteristic of the transition series.

Out of 143 species of mollusca in this list, 16 are marked as also occurring (for the most part plentifully) in the carboniferous system. The localities which produce these shells are the Devonshire limestones before mentioned, Blankenheim, Lake Erie, Shropshire, and the country about New York. We recommend the further consideration of this subject to the special attention of Geologists, in connection with Mr. Murchison's recent discoveries in the upper slate system of Wales, in which all his researches appear to show a constant and complete difference between the fossils of the transition series and those of the carboniferous limestone, separated from it by four thousand feet of old red sandstone.

ANNULOSA.

Serpula epithonia, G.		Bensberg.
ammonia, G.		Eifel.
omphalodes, G.	Michel Dean, Gloucestershire	Ditto, Bensberg.
socialis, G.		Ditto ditto.

CRUSTACEA.

Family.	Name.	British Localities.	Foreign Localities.
Trilobites	Calymene Blumenbachii, Bt.	Dudley, Tortworth, Charfield, Shropshire	Ohio, Newport, Utica, Scania, Ostrogothia, Gottland, Eifel, &c.
	macrophthalma, Bt.	Dudley, Shropshire	Dusseldorf, Dillenburg, United States.
	variolaris, Bt.	Dudley, Ledbury, Herefordshire, Shropshire.	
	Tristani, Bt.		Eifel, Breuville, Falaise, La Hunaudiero, Rennes, Angers.
	bellatula, Dal.		Husbyfjoel, (Ostrogottland.)
	ornata, D.		Ditto.
	verrucosa, D.		Varving, (West Gottland.)
	polytoma, D.		Ljung, (West Gottland.)
	actinura, D.		Berg, (Ostrogottland.)
	schlerops, D.		Furudal, (Dalecarlia,) Ostrogottland.
	Schlottheimii, Bronn		Blankenheim, Daun, Gerolstein.
	latifrons, Br.		Ditto ditto ditto.
	concinna, D.		Gottland.
	protuberans, D.		Westphalia.
	punctata, Wahl		Gottland.
	lævigata, G.		Gerolstein.
	arachnoides, G.		Ditto.
	speciosa, Stensburg		Oeland, Röhman.
	æqualis, Meyer		Dillenburg, Herborn.
	Asaphus cordatus, Bt.		Gottland.
	caudatus, Bt.	Dudley, Ledbury, Tortworth.	
	cornigerus, Sch.		St. Petersburg.
	Hausmanni, Bt.		Ambresbury, Nehou, Prague, Catskill Mountains.
	De Buchii, Bt.	Llandilo, Bualt	Eifel, Cyer. (Norway.)
	mucronatus, Bt.		Mösseberg. (West Gottland.)
	expansus, Wahl	Dudley	Sweden, Norway.
	granulatus, Bt.		Varving, Olleburg, (West Gottland,) Furudal.
	extenuatus, W.		Husbyfjoel, Heda. (Ostrogottland.)
	Brongniarti, D.		Eifel, May, Nehou.
	angustifrons, D.		Husbyfjoel.
	Heros, D.		Kinnekulle, Wikarby.
	platynotus, D.		West Gottland.
	frontalis, D.		Ljung.
	læviceps, D.		Husbyfjoel.
	palpebrosus, D.		Ditto.
	crassicauda, W.		Ditto, Christiania, Tzarkos-zelo.
	dilatatus, D.		Norway.
	auriculatus, D.		Karlstein.
	Bucephalus, G.		Eifel.
	armatus, G.		Ditto.
	Schroeteri, Schl.		Reval.
	velatus, Schl.		Ditto.

Family.	Name.	British Localities.	Foreign Localities.
	Asaphus, myops, Kœnig	Dudley.	
	pustulatus, Schl.		Gottland.
Asaphus, Bt. Illænus, Dal.	centaurus, D.		Oeland.
	centrotus, D.		Husbyfjoel.
	laticauda, D.		Osmundsberg. (Dalecarlia.)
	crassicauda, D.		Husbyfjoel, Christiania, Tzarko-szelo.
Asaphus, Bt. Nileus, Dal.	armadillo, D.		Husbyfjoel, Skarpasan, Scania, &c.
	glomerinus, D.		Husbyfjoel.
Asaphus, Bt. Amphyx, Dal.	nasutus, D.		Ditto, Skarpasan, Varving.
	Ogygia, Guettardi, Bt.		Angers.
	Desmarestii, Bt.		Ditto, Gerolstein.
	Wahlenbergii, Bt.		Ditto.
	Sillimani		Mount Schnectady. (North America.)
Paradoxides, Bt. Olenus, Dal.	Tesrini, Bt.		Olstorp, (West Gottland,) Ginez, (Bohemia.)
	Sulzeri, Bt.		Ginez.
	spinulosus, Bt.		Andrarum, Scania, West Gottland.
	gibbosus, Bt.		Kinnekülle.
	scaraboides, Bt.		Falköping, (Ostrogottland,) West Gottland.
	Hoffii, G.		Ginez.
	Bucephalus, Wahl		Olstorp.
	macrocephalus, G.		Eifel.
	flabellifer, G.		Ditto.
	Agnostus pisiformis, D.		Kinneküllo, Mösseberg.

The greater part of these crustacea are peculiar to the slate system, and are distributed extensively along its range, generally in the upper slates and calcareous beds. No trilobite has yet been found in these strata in Scotland, Cumbria, Cornwall, or Ireland, but many species occur at Dudley, in Shropshire, Herefordshire, and South Wales, as well as in Sweden, Norway, about St. Petersburg, the Harz, the Eifel, at Angers, and in North America. Several species yet undescribed belong to the carboniferous limestones of England, which appear different from those of the transition limestone.

Fishes.

Traces of fishes have been found at Dudley, Tortworth, and in the Eifel.

General Summary.

There are 553 species of organic remains, of which 49 are also found in the carboniferous limestone *more abundantly*. The principal localities for these species in the slate system are Devonshire and the banks of the Rhine. If we include the shells of the South of Ireland, the repetitions of species amount to 62.

Plants	14	species, of which 4 are marine, 10 terrestrial.
Polyparia	87	fibrosa 7, corticifera 2, cellulifera 44, lamellifera 34.
Radiaria	31	
Conchifera	206	plagymyona 55, mesomyona 23, brachiopoda 128.
Mollusca	143	gasteropoda 64, cephalopoda 79, of which 11 are monothalamia.
Annulosa	4	
Crustacea	65	
	553	species, all marine, except a few plants.
Fishes		

Secondary Strata.

Carboniferous System.

Physical geography of the period.

At the commencement of the second great period in the deposition of the stratified crust of the Earth, that during which the secondary strata were deposited, the surface of the Globe, as far as this can be known from observations so long posterior, was in a very different state from that which has been inferred to have been its condition before the deposit of the primary strata. *Then* it is probable that little dry land existed, and perhaps most of the mechanical aggregates of the primary series were produced by agitations of the comparatively shallow waters of the Ocean; but *now* many mountain ranges and groups may be traced dividing the Ocean into seas and gulfs of various depths and unequal area, within which materials swept forcibly by inundations from the land were mingled with chemical precipitations from the water. Thus the primary ranges of Scotland, England, Wales, and Ireland, the South of France, and the North of Germany, are in many parts enveloped in thick strata of conglomerate sandstones, shales, coal, and limestone; and these deposits begin to assume more local characters, dependent on the varying Physical conditions of the particular case.

The shales and sandstones, which are evidently the result of the mechanical action of water, contain the reliquiæ of plants in great abundance, and the coal seams are wholly formed from the matter of terrestrial vegetables; but the limestones are full of marine shells, corals, and radiated animals. From the former we learn the condition of the land, from the latter that of the sea. The high temperature during the deposition of the primary strata, indicated by the remarkable consolidation of the rocks before the carboniferous era, may likewise be inferred from the tropical character of the plants associated with the coal seams, and the coralline and other zoophytic animals embedded in the limestones of the carboniferous epoch. To this period likewise belong many mineral veins, many eruptions of basaltic rocks, and other effects of internal heat.

The carboniferous deposits are generally very distinguishable from those of the primary group; most remarkably so, where, as is generally the case, their accumulation was preceded by a great elevation of the slate mountains: but in several instances the change from the older slates to the shales and sandstones of the superior group is very gradual, (*Herefordshire*,) and unaccompanied by violence, and the organic remains are mostly congenerous. It is not then a new Creation, nor even a new System of Nature, that we are called upon to examine, but another step in the scale of periodical operations, whereby the vacant Planet was replenished with life, and fitted for the residence of Man.

Divisions of the system.

In England the carboniferous system, when fully expanded, admits of division into three series:

The old red sandstone,
The carboniferous limestone,
The coal formation;

and in many parts, (Somersetshire, Monmouthshire, Derbyshire, &c.) these are not only distinguishable but even strongly contrasted; the first by its red sandstones, and conglomerates derived from the neighbouring primary mountains; the second by its almost undivided mass of limestone full of marine exuviæ; the last by its shales and argillaceous sandstones, bands of ironstone, and beds of coal. But, in Yorkshire, the limestone series begins to be intermingled with coal, sandstones, and shales; in the Northern parts of Northumberland these two series are intimately blended; and in the Island of Arran the diminished deposits of coal and mountain limestone are included, and almost lost in one vast mass of red sandstone, with no clays and conglomerates.

There is nothing peculiar in this: we shall find exactly similar phenomena among the superior formations. In fact, it is certain that among all the formations posterior to the slates, the distinctions of strata are mostly local, and even the formations themselves, however extensive, are limited within the circuit of the anciently elevated primary mountains. Nevertheless, the red conglomerates when present usually appear at the base of the carboniferous system, and the coal deposits are most plentiful at the top. This appears a natural consequence of the state of the Earth's surface when the formation began. The conglomerates should be most abundant in the oldest deposits, because they are evidently the result of the transient violence attending the elevation of the primary strata which they surround; then, in the sea, the period of succeeding tranquillity is marked by the most decided accumulation of marine spoils; and these, according as they took place in deep water or near the shore, retain a pure oceanic character, or are mingled with the spoils of the land, which, increasing in quantity, finally buried them under the vast mass of coal measures.

In describing this series we shall confine ourselves principally to the British Isles.

Old Red Sandstone Formation.

Origin of this formation.

In most cases the production of this rock is evidently the effect of general convulsive movements. The slate rocks of Cumbria, exposed upon their recent elevation to enormous waste and degradation, were rolled to pebbles, which were collected into hollows or rude valleys, and reunited by a basis of red sandstone or red marl into vast irregular beds of coarse conglomerate.

The mountains of Scotland are in the same way bordered by enormous accumulations of the same character; and those of North and South Wales are flanked by extensive deposits of pebbly red sandstone.

This lowest member of the carboniferous system, though varying in character in every different cliff and district, and irregularly distributed, is an extensive and important mass of strata.

In the Cumbrian district.

The limited tract of old red sandstone adjoining to the slate district of Cumberland and Westmoreland, lies principally on the Eastern side, where it appears in patches, in Mell-fell, at Dacre Castle, Sedbergh, and Kirby Lonsdale, and near Kendal. In all these situations it is a very coarse conglomerate, with a basis of red sandstone or red marl, filled with fragmented masses, almost entirely derived from the neighbouring slate hills. Some of these fragments are quartz veinstone with micaceous iron ore. Each little patch of conglomerate is nearly confined to a particular valley, and seems, in fact, to have been accumulated by currents which in the ancient times of disturbance passed down that hollow. No organic remains have ever been found in this rock around the district of the Lakes. In some places the quantity of pebbles is diminished, and the red sandstone forms separate beds; (Shapwells;) in other places the red clay, alternating with blue and white layers, (as at Kirby Lonsdale,) so closely resembles the new red marl, that nothing but the Geological relations could determine the difference of the deposits. As might be expected in such a heterogeneous mixture, the beds and joints of the conglomerate beds are irregular, and it deserves attention that hitherto no mineral veins have been found to traverse it. Veins of calcareous spar occasionally divide it, and, what is remarkable, the pebbles are often split by these veins, as they are in the contemporaneous conglomerate of Oban in Argyleshire, and the more recent Nagelflue of Swisserland.

It appears from these circumstances, that during the period of turbulence which succeeded the deposit of the slates in Cumberland, the waters of the sea had a particular tendency to deposit, near the shores, materials charged with red oxide of iron, and that the comparatively quiet process by which sandstones and clays were thus produced was liable to violent interruptions, and the products in consequence mixed with a vast quantity of fragments of the preconsolidated rocks, probably urged downwards to the sea along the lines of dislocated strata which had already begun to be excavated into valleys.

In Wales.

Along the South-Eastern and Southern border of the slate district of Wales, through Herefordshire, Monmouthshire, Glamorganshire, and Pembrokeshire, the old red sandstone formation is much more fully developed than in the lake district of the North. It is vastly thicker, more extensively spread out, composed of various definite parts, and consequently more regularly traceable through the country. Its boundary on the West is by Caermarthen, Brecon, and Leominster. On the East it runs from near Cardiff, by the high district of Wentwood, Trelech, and Craig y Dorth, and by the Forest of Dean, which it encircles with a high boundary edge to near Leominster, where it seems to end abruptly. Its thickness in Monmouthshire and Breconshire can hardly be estimated at less than 2000 feet; but its lower edge is not always clearly distinguishable from the greywacke slates beneath.

Monmouthshire, &c.

One of the best sections of the old red sandstone is afforded in the neighbourhood of Monmouth, beginning with the Kymin Hill, which is part of the lofty boundary of Dean Forest.

Here we perceive that the thick conglomerate rocks, full of quartz pebbles, remarkably analogous to some varieties of millstone grit, form the very cap of the whole system, and crown the hills with magnificent precipices and solitary crags. Below is a series of red sandstone rocks, productive of excellent flagstone, with one, or perhaps two, beds of a singular limestone, mottled with red, blue, green, and yellow, sometimes much mixed with clays, and always irregular. Though of argillaceous aspect, it is so nearly pure as to be burned to lime; and though apparently fragmentary, is really a very hard stone, fit for the roads. It contains no organic

remains. The lowest part of the section exhibits an extreme abundance of red marls with white and green bands, undistinguishable from those of the new red marl.

These characters accompany the range of the old red sandstone through the lower parts of Monmouthshire, and through Herefordshire, and part of Worcestershire, where the upper conglomerates are used as cyder mill-stones, and the limestone (called cornstone) is often employed on the roads.

This limestone, indeed, notwithstanding its apparently irregular and fragmentary character, is one of the most persistent layers that we are acquainted with, for it accompanies and characterises the old red sandstone along nearly its whole course. In Caermarthenshire it is particularly remarkable in the cliffs near Laugharne, from which specimens may be obtained not distinguishable from the "gooseberry" stone of Monmouth.

Scotland. The old red sandstone is largely developed in Scotland, especially along the South-Eastern edge of the Grampian mountains, and on the North-Western side of the slate ranges of Lammermuir, as fully described by M. Boué. As before observed, it forms in Arran the lower portion of one vast red sandstone series, the upper portion of which, not very different in any of its characters, is taken by Murchison and Sedgwick for the representative of the new red sandstone of England.

On the Western side of Scotland the old red sandstone is found at many scattered points in bays and hollows of the mountains, and has received very good illustration from Macculloch and the Geologists above named. Along the Caledonian Canal and in Caithness, strata of this age abound, and the Orkneys appear to consist chiefly of the same group of rocks.

Almost universally this red sandstone system, how various soever in thickness and in quality of composition, consists in all the lower portion, which rests upon the slate system, of a coarse conglomerate sandstone, generally tinged red, full of fragments large and small, and rounded by attrition in water. This rock does not, like that of Cumberland, to which it is strongly analogous in composition, lie entirely in local hollows, but forms a continuous belt round nearly the whole primary district, where the border of this is distinctly seen, and rises into hills of considerable altitude, which are in this manner wholly composed of the ruins of the interior and still higher primary mountains. The contemplation of this remarkable rock in the vicinity of the beautiful Lakes in the South-West part of the Grampians, can hardly fail to impress upon the attentive observer two propositions of the highest importance in Geology. 1st. That the accumulation of these mountainous ruins of earlier rocks was caused by the violence of water, put into activity by the elevation of the primary rocks, and favoured in operation by the fractures which this operation produced in them. 2d. That, since all these effects, the whole region of primary and derivative rocks has been again elevated, perhaps by a more insensible process, so as to raise the conglomerates to the height of 1000 feet or more above the level of that sea in which they were formed.

According to the nature of the primary rocks in its vicinity, as remarked by M. Boué, the red sandstone conglomerate varies in composition. The degree of attrition to which the fragmentary masses which it includes have been exposed, is here different in different places; without doubt according to the degree and continuity of the aqueous action accompanying the disruption of the primary strata. Thus on the banks of Lochness, at the Fall of Foyers, we find it a sort of granitoid breccia, with fragments slightly rolled of quartz, mica slate, red granites, primary limestones, &c. We might easily admit that this granitoid breccia is in some degree *metamorphic*, like certain breccias of Plutonic aspect in the slate district of Cumberland. The brecciated character, so remarkable at the Fall of Foyers, is speedily changed at a small distance into the usual aspect of a decided conglomerate.

Along the South-Eastern edge of the Grampians, the composition of the conglomerate appears dependent in a high degree on the nature of the primary series on which it reposes. Near the granitic and porphyritic region of Aberdeenshire, quartz, felspar, porphyry, granite, with garnets, sienite, hornblende, compact felspar, are mentioned by Boué, with gneiss, mica slate, and clay slate. But in the district of Loch Katrine, where Plutonic rocks are less abundant in the slate system, the fragments consist almost wholly of mica and chlorite slate. In Oban we have observed that the rock contains not only masses of trap rocks, but that its base is in places almost wholly composed of the substance of those rocks, reduced to sand. Along the Lammermuir ranges, which are composed of clay slate and trap rocks, the conglomerates contain almost wholly slate fragments and boulders, and lie in hollows of the chain, very much as the contemporaneous deposits border the similar slates of Cumbria.

The inclination of the conglomerate strata is dependent on the configuration of the primary mountains, and there is no doubt that the stratification is for great lengths of country in irregular accordance with that of the older rocks; yet this dependence is chiefly observed along the lines parallel to the axis of elevation of the Grampians, and is even there liable to great exceptions. In the vicinity of Loch Lomond it succeeds clay slate; generally along the Grampians it rests on mica slate or chlorite slate; but along the Lammermuir hills on greywacke slate.

Receding from the border of the mountains, the upper strata of red sandstone are found nearly free from pebbles, composed of laminæ of various quality, sandy or argillaceous; and sometimes, as in Perthshire, variously coloured. The greater part of the sandstones of Caithness, which are usually ascribed to this era, are dark, carbonaceous, flagstone rocks, in a few places containing between their layers very interesting specimens of fishes, which have been conjectured to belong to fresh-water tribes. Laminated sandstones abound in the Orkneys. Red sandstones accompany the coal of Dumfriesshire, and in this part of Scotland we believe that the red sandstone series is, like that of Arran, a great continuous deposit, in which the carboniferous limestone and coal seams form merely the parting, not always traceable, between the old red and the new red sandstone systems. A natural classification, in all the Southern parts of Scotland, made without reference to other parts of the Island, would, we think, include the carboniferous and saliferous systems in one general term, the *red sandstone system* having, as subordinate groups, *the mountain limestone and coal strata.*

This should diminish the anxiety sometimes felt about *universal agreement in classification*, and encourage topographical Geologists to employ for the country they describe the arrangement of strata most suitable to develope the true local relations of the rocks.

Metallic veins are rare in the old red sandstone rocks,

but veins of crystallized earthy substances occur frequently. Carbonate of lime traverses it at Kirby Lonsdale; sulphate of barytes near Monmouth and South Saunox in Arran; sulphate of strontian occurs in it near Inverness; and asbestus in Kincardineshire. (Boué.) The joints in it are very irregular.

In Ireland. The mountain limestone, which underlays all the coal fields of Ireland, generally rests on old red sandstone, which is unconformable to the subjacent slates.

Mountain or Carboniferous Limestone Formation.

The carboniferous limestone is a rock of which the history must principally be studied within the limits of the British Islands, for it is no where else so much or so variously developed. Its romantic rocks border many of the most beautiful valleys of the South-West of Scotland, Northern and Central England, and encircle the wide primary regions of Wales. In Ireland, as Mr. Weaver observes, this limestone is the prevalent and characteristic rock in most of the Counties, except Derry, Antrim, and Wicklow.

The romantic channel of the Meuse runs for a considerable distance about Namur and Liege in a very remarkable range of carboniferous limestone, along the Northern side of the primary slates of the Ardennes, and is prolonged Eastward to the German side of the Rhine, near Dusseldorf, and continued Westward (beneath a wide deposit of chalk) to the neighbourhood of Boulogne. The coal deposits of Poland are based upon dark limestones of the same age as the carboniferous limestone of England, but in general the coal fields of the centre and South of France, of Saarbruck, of Saxony, Silesia, &c. appear to be devoid of this rock; but Mr. Murchison mentions its occurrence in the North-East of Bavaria and in Bohemia. It abounds in North America, accompanying coal and anthracite.

It has been before remarked, that the carboniferous limestone presents itself with a very different aspect in the Northern and Southern Counties of England. In Somersetshire, Gloucestershire, Shropshire, South Wales, North Wales, Derbyshire, and Leicestershire, this rock appears an immense, nearly undivided, calcareous mass, perfectly defined below by a hard contrast with the old red sandstone or greywacke slate which supports it, and as distinct above by the abrupt covering of sandstones and shales which accompany the coal.

Very rarely indeed in the Southern Counties, as in the rocky valley of the Avon at Clifton near Bristol, are any beds of red sandstone interpolated among the lowest strata of limestone; and it is only by a few unimportant partings of shale that the upper portion is at all assimilated to the incumbent series. The toadstones which irregularly interlaminate the thick limestones of Derbyshire are of igneous origin, and it is not, in proceeding Northward, till we arrive in the valley of the Ribble, that any decided alternation of mechanical deposits breaks into distinct groups the strata of carboniferous limestone. From this point Northward, almost in the ratio of distance, to the banks of the Tweed, the limestone becomes more and more divided by beds of sandstone and shale, accompanied by ironstone, fossil plants, and coal; and thus, under Ingleborough we have a nearly undivided calcareous mass 400 or 500 feet thick; but at Aldstone Moor no less than twenty different limestones, amounting altogether to 470 feet, obscured by the interposition of no less than 1686 feet of sedimentary strata.

Further North these mechanical admixtures increase in amount, while the calcareous strata diminish, and at length, in the Northern parts of Northumberland, the limestone district has become a valuable coal field.

To embrace the subject in its most interesting point of view, we shall commence our account of the carboniferous limestone with a description of its characters in the "Pennine Alps," which border the Western parts of Yorkshire and Durham, and the Eastern parts of Cumberland and Westmoreland, and we shall connect therewith the analogous arches of limestone, which begird the primary district of the Cumbrian lakes. Taking this as a type of the formation, we shall be able to compare with it the other localities in the British Isles and on the Continent of Europe.

This tract of country has been, for different objects, partially described by Professor Sedgwick and other Geologists, and their views, whether published or not, will be recognised in the following summary. The Cumbrian slates are surrounded for three-quarters of a circle, from Egremont to Ulverston, by a belt of limestone, which reposes indiscriminately upon the lower slate near Loweswater, the middle slates near Ulswater, the upper slates from Shap to Ulverston, and the old red conglomerate at the several points of Dacre, Sedburgh, Barbon, Kirby Lonsdale, and Ulverston.

The South-Eastern part of this circular belt forms part of a long range of limestone cliffs facing the West from Ingleborough to Tindal Fell, defined by one continuous line of elevation nearly 1000 yards in height. Prodigious transverse dislocations occur at these points, that at the Northern end ranges East and West, and causes an immense depression to the North, after which the limestones range North-East through Northumberland; that at the Southern end ranges West South-West and East South-East, and causes an equally striking depression to the South, after which the limestones show themselves locally, and in much disturbance, as far South as Clithero.

From the high Western escarpment before mentioned, the strata sink with a very regular inclination Eastward or South-Eastward, and are exposed in the valleys of the South Tyne, Derwent, Wear, Tees, Greta, Swale, Yore, Ribble, Wharfe, Nid, and Aire, bordering those streams with some of the boldest and most picturesque rock scenery in England.

The grand natural section of Ingleborough and Penygant presents us with the following series of rocks belonging to the carboniferous limestone.

		Feet.
1. Group above the limestone, commonly called millstone grit series	Alternations of sandstone and shale with bad coal on Penygant	100
	Millstone grit of Ingleborough	60
	Alternations of sandstone and shale	100
2. Upper belt of limestone	Thin limestone 8 feet; Shale 10; Main Great limestone 60	78
3. Alternations principally of shales and sandstones, some of them flagstones, with thin limestones		300
4. Great scar limestones with calcareous conglomerate beds at bottom		400

This series rests on slate rocks.

Proceeding Northward from Ingleborough we arrive in Wensleydale or Yoredale, and find the section modified as under:

		Feet.
Millstone grit series. 1. Above the limestone.	Coarse and fine sandstones, shales, and COAL. Coarse, fine, and slaty sandstones, shales, cherty beds, and COAL. Millstone grit of Ingleborough, shales, cherts, and COAL.	700
2. Upper limestone belt.	Thin limestone, sandstone, shale. Main or twelve fathom limestone. Shales sandstones and COAL, underset limestone.	200
3. Flagstone system.	Alternations of flagstones of various quality, in great abundance, with shales, COAL, hard gritstones, and three or four strata of limestone, from 6 to 30 feet thick. The black marble of Dent is nearly at the base of this group.	500
4. Scar limestones.	Limestones of great thickness, with partings principally of shale.	500

The series is incomplete, other limestones existing below.

Here it will be perceived the group No. 4. has become divided into distinct parts; and the calcareous portions of No. 3. are also more defined and more important. No. 2. has assumed that character of a decidedly double belt, which henceforward distinguishes it for a great distance to the Northward.

Our next station will be taken in Swaledale.

			Feet.
1. Millstone grit series.	Coarse gritstones, shales, finer sandstones, shales, and COAL.	600	800
	Variable series of thick shales, with sandstones and COAL, and local interpolations of limestone and chert.	200	
2. Upper limestone belt.	Limestone	3	252
	Shale, &c	63	
	Main or twelve fathom lime	72	
	Grit, chert, shale, and COAL	96	
	Underset lime	18	
3. Flagstone system.	Variable alternations of gritstone, flagstone, and plate, with three or four limestones from 6 to 30 feet thick.		340
4. Scar limestones	Of great thickness, but only partially exposed in the bottom of Swaledale		

The groups 1 and 3 have now become more complicated, and require further division as compared with the Ingleborough section, and thus we are gradually conducted to the still more developed series of Aldstone Moor, as described by Forster.

Group			Calcareous beds. yds. ft. in.	Other deposits. yds. ft. in.
1. Millstone grit series.		Alternations of sandstone, (coarse and fine) and shale		25 1 0
	1.	Felltop lime	1 1 6	
		Alternations of laminated and other sandstones, shales, ironstone, and COAL		109 2 8
2. Upper limestone belt.	2.	Limestone	3 0 0	
		Alternations, plate, &c. with COAL		16 2 0
		Limestone	21 0 0	
	3.	Parting		10 0 0
	4.	Limestone	0 1 6	
		Sandstone and shale and COAL		23 1 0
	5.	Underset limestone	8 0 0	
3. Flagstone system.		Sandstone and shale (Nattriss Gill Hazle)		17 0 0
	6.	Limestone	3 0 0	
		Sandstone and shale		15 1 6
	7.	Limestone (5 yards)	2 1 6	
		Sandstone and shale		10 0 0
	8.	Scar limestone	10 0 0	
		Thin alternations		15 0 0
	9.	Cockle-shell limestone	0 2 0	
		Alternations		5 2 6
	10.	Limestone (single post)	2 0 0	
		Alternations		20 0 0
4. Horn limestone.	11.	Tyne bottom limestone	8 0 0	
		Alternations in the upper part of which the "Whin sill" (igneous) occurs, (20 to 40 yards thick)		24 2 6
	12.	Jew lime	8 0 0	
		Alternations		8 2 6
	13.	Little lime	6 0 0	
		Alternations		30 0 0
	14.	Smiddy lime	10 1 6	
		Sandstone		4 0 0
	15.	Limestone	8 1 6	
		Alternations		7 0 6
	16.	Robinson's lime	7 0 0	
		Alternations		4 0 0
	17.	Great limestone, Melmerby scar	44 0 0	
		Alternations and COAL		8 0 0
	18.	Limestone	4 0 0	
		Alternations		55 0 0
	19.	Limestone	2 1 6	
		Alternations and COAL		73 2 0
	20.	Limestone	6 0 0	
		Alternations		78 0 0
			156 2 0	562 0 2

It is probable that even this section does not show us the full depth of the series.

We have for some time been occupied in endeavours to ascertain *exactly* the line which in the Aldstone section separates the groups 3 and 4 of Yorkshire, and the above result is very near the truth.

Combining together the preceding statements, we have the following results in total thickness:

Group.	Penygant.	Wensley-dale.	Swaledale.	Aldstone Moor.
1. Millstone grit series (incomplete series)	260+	700	800	409
2. Upper limestone belt.	80	200	250	247
3. Alternations, or flagstone system	300	400	250	304
4. Scar limestones	400	250+	120+	1196

In the following table the relative proportions of the calcareous and the other deposits are estimated:

Group.	Penygant. Limestones.	Penygant. Other deposits.	Wensleydale. Limestones.	Wensleydale. Other deposits.	Swaledale. Limestones.	Swaledale. Other deposits.	Aldstone Moor. Limestones.	Aldstone Moor. Other deposits.
1.	?	260	?	700	10	790	4	403
2.	70	10	100	100	93	157	97	150
3.	30	270	50	350	40	210	54	250
4.	400		150+	–100	80+	– 40	313	883
	500	540	300+	1250+	223+	1197+	468	1688

We must remark that this comparison is imperfect, because the sections are not in each case defined above or below by the same beds: in order to obtain a fairer numerical comparison, we may omit altogether the beds above the upper limestone belt, and, on account of its incompleteness, the fourth group in Wensley Dale and Swaledale.

We shall then have the following corrected scale:

	Penygant.		Wensley-dale.		Swaledale.		Aldstone Moor.	
Upper limestone belt	70	10	100	100	93	157	97	150
Flagstone system	30	270	50	350	40	210	54	250
Scar limestones	400	—	—	—	—	—	313	883
	500	280					464	1283

Had we, instead of Penygant, chosen Great Whernside for our section, we should have had the limestone of these groups about 100 feet, and the other deposits less than 200 feet; and if we had taken a section in Northumberland, instead of Aldstone Moor, the limestones would have been less than 200 feet, and the other deposits probably nearer 1000 feet. The principal changes, as we proceed Northward, appear to happen in the

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ower part of the limestone group, which loses its individuality by admitting between its beds a constantly increasing quantity of mechanical admixtures, and at length becomes a subordinate feature in a country which has the characters of a coal field. We shall now trace the course of the carboniferous limestone round the Cumbrian mountains, and through other parts of England.

Range of the mountain limestone.

The lower, or as we shall name it "scar limestone" group, passes Westward from Ingleborough by Kirby Lonsdale, Burton, and Cartmell to Ulverstone and Dalton; extending Northward to Kendal. (See Smith, *Geological County Maps.*) This group every where possesses the almost wholly calcareous character which it bears in Ingleborough. On the South of Ulverstone, it is covered by the intermediate grit and plate series with traces of coal, and a more extensive deposit of this kind South of Kirby Lonsdale, yielding useful coal and flagstone, is again overlaid by the upper belt of limestone and afterwards by the millstone grit series towards Lancaster.

Under Wild Boar Fell, on the borders of Yorkshire and Westmoreland, the scar limestones begin to exhibit, in consequence of dislocations, a double escarpment, the Western branch passes off by Ashfell, Orton, Shap, and Lowther, to the Eamont, and continues by Greystoke Park, Hesket, Ireby, and Cockermouth to Egremont. These limestones alternate in their lower parts with red sandstone, by some Geologists referred to the old red, and diminish in thickness Westward. They are overlaid by deposits of the grit and shale series near Shap, Hesket, Newmarket, and Bolton, but from Workington to Whitehaven the thick and abundant coal seams probably belong to the ordinary coal series above the millstone grit. There is, perhaps, unconformity here between the coal measures and the limestone, a case very rarely observed in England.

Agreeably to what has been said before the scar limestones, in passing through Northumberland, become continually more and more subdivided by interpolations of sandstone, shale, and coal, till on the sea-coast North of Belford, a part of this series contains no less than thirteen bands of limestone, (121 feet in total thickness,) separated by many times their thickness of sandstone and shale, and under the whole lie workable seams of coal. The character of the surface of all the Western and North-Western part of Northumberland corresponds to this change of the component strata. Instead of the beautiful green pastures which delight our eyes amidst the calcareous dales of Derbyshire and Yorkshire, wide, heathy, and boggy moorlands overspread the surface of sandstones and shales, and we seem to wander in a region of barren coal measures rather than on the range of the thickest carboniferous limestones. This may serve to explain the seeming anomaly in Mr. Greenough's Map, where this unquestionably carboniferous tract is represented as distinct from any of the strata in the British section. Mr. Smith colours the whole space as a coal tract.

On the contrary, in proceeding Southward along the [chain]ble, we find the lower scar limestones in great force about Clithero, surmounted by a considerable mass of shales with sandstones, corresponding to the shale and grit series of Ingleborough; above these, in Pendle Hill, appears the diminished upper belt of limestone, and, over all, the millstone grit series, here also occasionally yielding coal. Hence to Derbyshire, the scar limestones lie too deep to be seen, and the upper belt of limestone appears to be extinguished; so that this part of the Western boundary of Yorkshire is occupied by a vast thickness of the millstone grit series and the flagstone series, without any disclosure of the subjacent limestones, even in the deeply excavated valley of Todmorden.

In Derbyshire, putting out of the question the irregular interpolations of igneous rocks, called toadstone, we have the scar limestones more than 750 feet thick, surmounted by shale with their alternations of sandstone, *limestone*, ironstone, &c. 500 feet, and the hills are crowned by bold ranges of millstone grit, and its accompanying sandstones, 360 feet in thickness.

See pl. i. fig. 15. which expresses in general terms the *method of variation* of the carboniferous limestone and millstone grit series of the grand Penine chain.

South of Derbyshire we have no longer the same remarkable mass of strata interposed between the scar limestones and the proper carboniferous sandstones and shales. The limestone, wherever it occurs in North Wales, Shropshire, the Forest of Dean, Mendip, and round the coal field of South Wales, refers itself to the type of the scar limestones of Derbyshire, and it is only by a very imperfect representative in Shropshire and the Forest of Dean, and on the Northern border of the coal field of South Wales, that the millstone grit series can be recognised.

The limestone tract along the Meuse is evidently of the same era as the limestone of Derbyshire and Monmouthshire, and continually recalls to the delighted voyager the beauties of the Derwent and the Wye, but the strata above it are with difficulty compared with those of any part of the English basins.

Having thus compared in the most general point of view the component groups of the carboniferous limestone and millstone grit series in different localities, and ascertained the method of variation which it observes, we shall endeavour to describe some of the principal characters of these several groups.

Scar Limestones.

General characters of the rock

The carboniferous limestone, though by no means of one uniform aspect or chemical composition, possesses, nevertheless, a certain range of mineralogical characters which are scarcely to be recognised in any of the other secondary calcareous deposits. It is usually a nearly pure carbonate of lime, of a greyish or even very blue tint, of considerable hardness, and imperfect conchoidal fracture. Some of the varieties are very dark coloured, and even quite black, (Swansea, Abergavenny, Kilkenny, Derbyshire, Yorkshire,) but the latter commonly contain a minute admixture of argillaceous and bituminous matter. Many varieties exhale a fetid odour on being rubbed or bruised. In Derbyshire, and generally along the Yorkshire and Westmoreland ranges, the scar limestones contain considerable beds of a granular and even brecciated limestone capable of being employed as good freestone, and some layers in Derbyshire and Westmoreland appear almost wholly composed of crystalline grains, and contain magnesia. A crystalline variety in Derbyshire is mixed with red oxide of iron. In the country about Burton in Kendal, and Clifton, near Bristol, the stone is often decidedly oolitic, and even exhibits considerable variety in this respect. The lower layers which rest upon the slate on the Craven mountains, at Kendal, and near Penrith, are filled with large and small boulders of the slate, so as to become a real conglomerate.

But the most decided characters of these rocks are the organic remains, all of which are different from those of the strata above. The prodigious abundance of productæ, spiriferæ, terebratulæ, and other shells, of lamellated corals, and above all, of crinoidal remains, will almost always enable even the tyro to pronounce on the identity of the mountain limestone. Crinoidal remains, in particular, are so excessively abundant in certain parts as to constitute fully three-fourths of the mass of the rock.

Chert beds and nodules. A remarkable character is imparted to vertical sections of this rock in the Mendip hills, in several parts of Derbyshire, and the neighbourhood of Clithero, by nodules of chert imbedded in the limestone, often at regular distances, like the flints in chalk. A very striking section of this kind is seen in Vallis Bottom, near Wells. This chert is usually of a dark grey, or even black colour, but occasionally it is white, and in general its colour corresponds to that of the limestone beds which contain it. It rarely contains any organic nucleus, and thus differs from a large proportion of the flint nodules in chalk, with which, in the manner of its production, and in its relations to the calcareous rocks, it seems otherwise very analogous. The cherty layers in green sand and coralline oolite are also analogous instances, and we have hereafter to notice a similar character in a certain portion of the magnesian limestone. Proceeding Northward, as the limestones are divided, these chert nodules are less plentiful, though in Coverdale, in Yorkshire, they abound, and at Glenwhelt, on the Roman wall, shells of the genus *Bellerophon* have been detected in a very dark chert imbedded in the limestone there.

Chert beds. The curious circumstance of conversion, as the miners say, or rather substitution of beds of chert for beds of limestone, generally at the top of the rock, is noticed in most parts of the limestone tract in England and Wales; and very often it happens, as in Westmoreland, that the corals are converted to silicious matter in the midst of a block of limestone. It is probable that the substance resembling rottenstone of Dentdale, Swaledale, and Aldstone Moor, may be occasioned by decomposition of this chert, but Mr. Farey thinks the rottenstone of Derbyshire is owing to a decomposition or change of the shale limestone near the surface. A specimen collected by the author at Aldstone Moor in 1820, which as to substance is a kind of rottenstone, is evidently decomposed chert, and contains several fossils of the limestone series, especially a very small species of trilobites. Similar facts are common in the Yorkshire dales.

Bitumen in solid masses lies very frequently in the beds of the scar limestone, and enters the cavities of productæ, orthocerata, &c.; as at Castleton, and near Clithero. In a liquid as well as solid state it will be noticed under the next division of the carboniferous strata.

Physical geography. The surface of the country which is occupied by this rock in England is remarkably characteristic. Having been exposed to many repeated convulsions, it is thrown up to considerable altitudes, and placed in a great variety of positions favourable for the exhibition of the changes wrought on it by the atmosphere and streams. It is principally to the hardness and comparative durability of this rock, conjoined with its stratification and extensive system of *joints*, that we owe the grand ranges of vertical escarpments, which begird with a perpetual fortification the sides of the dales of Yorkshire and Derbyshire. Often, indeed, the wasting effect of the elements is sufficient to excavate vertical rents and to insulate the great prisms of the rock which, especially in Dovedale and other parts of Derbyshire, give the most romantic features to the valleys, while the same effects upon the high scars in Yorkshire and Westmoreland show like towers and bastions projecting from the wall of rocks or among the green herbage which has spread around them.

Frequently upon broad surfaces of limestone, especially where it alternates with shale, we find ourselves suddenly stopped by a deep vertical pit in the rocks, worked by some little rill, or even by the mere gathering of rains, an effect more frequently observed in the course of streams, which, like the Calder in Cumberland, traverse the ranges of this rock. These "swallow holes," as they are justly called, often serve to mark out uninterruptedly for miles the lines of limestones, whose actual edges may be obscured by the sliding of other matter over them. Swallow holes.

These swallow holes sometimes communicate downwards with internal caverns, which are nowhere so abundant as in the lower or scar limestones. It is to them we must refer the numerous caverns of Mendip hills, in Somersetshire, the rocks of Clifton, the Forest of Dean, the celebrated caverns of Staffordshire and Derbyshire, and those beneath Ingleborough and Penygant, in Yorkshire. Further North, along the Penine chain, where these limestones grow thinner, the caverns become less numerous, and in the same proportion the phenomenon of underground streams is rarely observed. This remarkable phenomenon is evidently dependent on the thickness, as well as on the open joints and absorbent surface of the rock, and examples of the same kind occur in various other thick calcareous strata of England, as the oolites and chalk, as well as in the Jura limestone or oolite of Germany and France. It is to the same causes that we must ascribe the extraordinary strength of the springs which issue as clear as crystal from the openings of this rock: but, being highly charged with carbonate of lime, soon deposit along their channel abundance of tufa. The herbage upon this limestone is usually short, elastic, and nutritious, and of a lovely green, which contrasts strongly with the bluish aspect of the moist surfaces of the shales, and the brown tints of the heathy moorlands of millstone grit.

Flagstone Series.

The shale and grit, or flagstone series above the scar limestones, is called in Derbyshire the limestone shale. It is about 500 feet thick, and consists principally of black or brown rather durable shale, forming a very wet soil, and causing land slips of great extent beneath the millstone grit summits. Mam Tor, the "Shivering Mountain," near Castleton, exhibits these characters very decidedly. The shale, however, is interstratified to a great extent, and with a considerable regularity, with thick rocks of fine-grained micaceous gritstone, of excellent quality for building, and, as we have observed, generally at the bottom of this rock, with good durable micaceous flagstone, very similar to that in the more recent coal strata. Some less regular sandstone beds, called "Cankstone," approach very nearly to the nature of the ganister or calliard rocks of the coal strata. Mr. Farey, who considers these *interpolations* as *anomalies*, calls by the same name the very characteristic beds of black argillaceous limestone which lie in this shale, at Ashford, near Bakewell, and near Ashborne, and produce lime fit for water cement. The frequent contor- In Derbyshire.

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tions of the limestone and shale are noticed by Mr. Farey as very remarkable. Ironstone balls lie in bands in this shale, a few *impressions of fossil plants* have been collected, and very thin coal seams observed, not worth the expense of the fruitless trials in search of them. Liquid bitumen is mentioned at several points in connection with the limestones in this shale.

In Yorkshire.

This description of the Derbyshire limestone shale would apply with scarcely a varying sentence to the broad argillaceous strata which cover the thick limestones of Craven. The same abundance of shale, occasional interpolations of sandstone, ironstone, and laminated beds of dark limestone, the same traces of coal and liquid bitumen, the same contortions, may be traced in Craven and in Wharfdale. More divided by sandstones and limestones, the same shale is recognised in Pendle Hill, Ingleborough, and Penygant. The locality most remarkable for the abundance of liquid bitumen is at Flasby in Craven, where Mr. Preston has excavated a considerable quantity of the black argillaceous limestone, and found it associated with abundance of nautilus sphericus besides large orthocerata and the curious fossil formerly supposed to be a pleurobranchus. The nautili are generally inverted or have their cavities filled with liquid bitumen, and small solid lumps of the same substance are likewise met with. This, amongst others, is one strong reason for believing that the darkness of colour of these limestones and shales is due to the admixture of carbonaceous matter.

By a recent communication of Sir Philip Egerton and Lord Cole to the Geological Society, we have learned that the lower coal shale, as it has been termed in the Western Irish coal fields, is precisely analogous not only in mineralogical characters, and in its geological position between the mountain limestone and the true coal measures, but also in its organic remains, to the "limestone shale" of Derbyshire and Craven. The same ammonites, the same posidoniæ, (Bronn,) and other characteristic fossils occur in these far separated districts; and in general, so strict is the accordance in all respects, that no Geologist accustomed to the strata of the North of England, could fail to recognise in the mountains above Enniskillen an exact analogy with Ingleborough and Great Whernside.

Penine chain.

In the further continuation Northward of this series of shales, sandstones, and limestones, the limestones, as before observed, thicken, the alternations of sandstone and shale therefore become more frequent and divided, coal seams intervene, and the whole assumes the character of a complicated coal and limestone deposit. It is possible, in tracing the different limestones enumerated in this series, to assign characters of local permanence. Thus the beds most remarkably stored with crinoidal reliquiæ, are those of the "main lime," in Pendle Hill, Ingleborough, Cam Fell, &c.; the black limestone of Whalley, Kirby Lonsdale, and Dent, is almost wholly deprived of them, like the same beds in Derbyshire; productæ abound on the top of the main lime, caryophylliæ are often plentiful in the beds below it, and one thin bed of limestone, at Aldstone Moor, receives, in consequence of the nature of its organic contents, the name of Cockleshell Lime. Chert lies frequently on the top of the main lime, and underset or four fathom lime beneath it, as well as on the top of the little lime or crow lime above it. Slaty sandstone yielding flagstone occurs both in the alternations under the main lime, and in those still lower between the underset and scar limestones. In one or other of these places in the section, flagstones are dug in Swaledale and Yoredale, in Graygarth fell, near Kirby Lonsdale, and Garstang, and it is probable that the flagstones of the North of Derbyshire belong to the same epoch. In some of the very hard sandstones which occur in this series in Swaledale, (like the cankstone of Derbyshire,) stigmariæ and other fossil plants occur, but in general the coal seams are not accompanied by many vegetable remains.

A kind of rottenstone, as before mentioned, occurs in this series in Dentdale and at Aldstone Moor, and probably in many other places is produced from the decomposition of the chert.

The shales of this tract are usually dark, close, and fissile, and traversed by immensely long straight joints ranging North by West, and South by East, East North-East and West South-West, dividing the rock into rhomboidal prisms. They often contain nodules of ironstone. A very remarkably indurated flinty shale, fit for use on the roads, which occurs in Swaledale and Yoredale above the main limestone, is called "Black beds."

The sandstones vary as to fineness of grain, and some of them in their progress through Northumberland assume such a coarseness of aspect, as to be in fact undistinguishable from the "millstone grit" of the next group.

The marine fossil remains are almost wholly confined to the limestones and the cherts which sometimes replace them, but the few vegetable remains belong wholly to the sandstones and to the coal.

Coal field of Midlothian

In the Midlothian coal field in the Counties of Edinburgh, Haddington, and Peebles, Mr. Farey sen., in 1816, ascertained 337 principal alternations of strata between the surface in the town of Fisher Row on the banks of the Frith of Forth, (where the highest of these strata occur,) the commencement of the basaltic rocks forming the general floor and border of this important coal field. These strata lie internally in the form of a lengthened basin or trough, and consist of sandstone, shale, coal, limestone, ironstone, &c. 66 seams of coal, counting the double seams as one; 7 limestones; 72 assemblages of stone and other sinkings; in all 5000 feet in thickness.

Upper Limestone Belt.

The only additional remarks which we shall make on this portion of the strata refer to the remarkable variation of character, by which the limestone in several places is gradually changed to or suddenly replaced by chert. Thus in Swaledale the united thickness of the underset chert and underset lime (the former being uppermost) is nearly constant, but the thickness of each is extremely variable. In like manner in Wharfdale, about Kettlewell, the underset lime just before it expires entirely under Great Whernside, is represented only by hard chert, and the main lime of the same district before it thins out and dies away becomes remarkably cherty, both by the change of whole beds and the introduction of chert nodules. There appears some reason to attribute this effect, in one case, to the operation of a vein, while in others it may, perhaps, be properly viewed as indicating merely the suppression of the calcareous deposit independently of the silicious. It must be owned, however, that the notion of miners, and that first suggested to the Geologist, agree in assigning the

effect in some instances, even independent of dykes or veins, to a real chemical conversion of the nature of the rock since its deposition.

Millstone Grit Series.

Mineral composition.

The difference of composition between the coarse sandstones which abound in this part of the series, and those of finer grain which alternate with the limestones below and the coals above, is rather apparent than essential. That all these sandstones are composed of the broken and triturated ingredients of older crystalline, generally granitic compounds, is evident upon inspection. Their most abundant ingredient, sand, is plainly in the state of minute pebbles, and the size of these grains is sometimes so very small, that their coherent mass assumes almost a crystalline aspect, as, for example, in the Calliard stones. On the other hand, in millstone grit they are of all sizes under an egg, though pieces of greater size than this are sometimes seen. These are evidently quartz pebbles of different kinds, corresponding to the quartz of veins and of granites. Rose quartz also has been observed. The next abundant ingredient is felspar, which is probably present in all these sandstones. In the millstone grit this mineral occurs in *rounded pebbles* whose *internal structure is perfectly crystalline*, like the large rhomboidal crystals in the porphyritic granites. Hence we learn clearly the history of such a sandstone deposit. The materials were derived from crystallized rocks, and were subsequently more or less rolled about and deposited in water. Mica, the third ingredient of granitic rocks, is less abundant in millstone grit, except in certain layers where it is occasionally very plentiful. It is usually of a pale silvery colour and is in very thin fragmentary scales. The decomposition of the felspar leaves a white, soft, unctuous substance, analogous to the kaolin of decomposed granite, and this forms a feeble cement for the grains of sand and mica. Occasionally in millstone grit, as in the other sandstones of the carboniferous system, we find oxidulous iron and some other mineral substances not easily recognised, and in Lancashire, frequently, fragments of shale, coal, &c. Every thing, therefore, concurs to prove the mechanical watery origin of millstone grit, and by consequence of all the other sandstones associated with it, the differences between them being only of degree. In the same manner nearly a gradual series of changes assimilates sandstone and shale, and it is sufficiently proved that the only really chemical aqueous deposit of this whole system is the limestone.

The millstone grit of the Southern coal fields is usually a much harder and more compact and cherty rock than the coarse pebbly strata which bear this name in the North of England. Finally, we must repeat the remark previously made that this series is limited in extent, not being of much importance or really characteristic of a certain period except between the Trent and the Tyne. Through the remainder of Northumberland it is less remarkable than several other equally coarse grit rocks, called crag grits in Mr. Smith's Map of Northumberland, which lie in the limestone series considerably below the upper limestone belt. Excellent building stone is furnished by this rock in Yorkshire, Lancashire, and Derbyshire, and by its representative, the "Farewell Rock" of Dean Forest and South Wales, which have the valuable property of standing great heat, and are therefore employed in certain parts of the iron furnaces.

THE COAL FORMATION (OR COAL MEASURES) consists of alternating strata of sandstone, shale, and coal, with courses of nodular ironstone, layers of bivalve shells, and, in a certain part, argillo-calcareous balls and nodules generally enclosing ammonites, pectens, &c.

None of these strata differ individually in any essential points from the analogous deposits in the millstone grit, or limestone series beneath; their characteristic features are derived from their combination. It is, indeed, generally true, that the sandstones of the coal measures are softer and more argillaceous than those of the series below, that the coal shales are less indurated and less fissile than the "plates" of the limestone group, and the coal generally of better quality. But it is by the *greater abundance* of the coal seams, and by the *absence* of limestone beds that the upper part of the carboniferous system is to be distinguished from the lower. It is, therefore, perfectly conceivable, that cases may occur when the lower or calcareo-carboniferous group may, by the attenuation of its limestones and the thickening of its coals, become so similar to the upper group or true coal measures, that their relative ages can be only determined by collateral evidence. This extreme case has, indeed, hardly yet been observed in any of the known coal districts of the New or Old World, but the approaches to it in Northumberland and Scotland are sufficient to show that the coal measures have no other real difference from the lower parts of the carboniferous system, than the *total* absence of the oceanic deposit of limestone. In many coal fields the reason of this difference is easily determined by the abundance of *fresh-water shells*, beds of shale, and of ironstone, alternating with the coal.

We have seen with what certainty the range of the mountain limestone can be followed through Great Britain, and its detached portions referred to their true place in the series of its beds, and thus Geological parallels be established between the Mendip Hills, Derbyshire, Yorkshire, and Northumberland. The coal measures of Great Britain cover quite as large a surface, and are, perhaps, quite as well identified *in mass*; but the details of the several coal fields are too discordant, to permit many of these parallels to be drawn, without which the *method of variation* by which one such coal field becomes different from another cannot be determined. This is so entirely well known, that often in the *same coal field* the differences are so considerable as to render it difficult to identify the beds of the two extremes. It must be owned, however, that this is partly owing to the confusion of nomenclature amongst the workmen, though principally to the sudden changes of chemical quality to which the coal seams are liable.

The extent of the coal fields of England and Wales may be seen upon Mr. Smith's and Mr. Greenough's Geological Maps; those of Scotland also are sketched upon Mr. Smith's Map; Mr. Griffith's Surveys and Mr. Weaver's observations have contributed much information on the coal measures of Ireland, and many valuable notices in the *Annales des Mines*, *Annales des Sciences Naturelles*, &c., make us acquainted with the same series in France. For the Netherlands the same Journals and the Memoirs of Omalius d'Halloy, and for the German and Transylvanian coal fields the works of

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Villefosse, Freisleben, Hoffman, Sternberg, and others may be consulted. Mr. Conybeare has given a general view of these foreign coal tracts in the Geology of England and Wales.

English coal fields.

We shall consider the characters of the principal English coal fields in the following order:

1. The great Northern coal fields of Northumberland and Durham, Yorkshire and Derbyshire, and their appendages.

2. The South-Western coal fields of South Wales, Dean Forest, Somersetshire, and Kingswood.

3. The coal fields of North Wales and Shropshire.

4. The central English coal fields.

That the great Northern coal fields of Northumberland and Durham, and of Yorkshire and Derbyshire, were formed under very similar circumstances, and, if never connected towards the borders, were united in the deeper parts of the deposit, will appear from the following comparisons. The Northern and Southern portion of this great tract, though now separated sixty miles, agree in being formed within a belt of coarse pebbly sandstones (millstone grit) associated with thin coals, which overlay the mountain limestone, and in being covered *unconformedly* by the magnesian limestone. Coals of like quality are worked in these coal fields in the same parts of the series, bituminous coals of excellent quality in the lower part, quick-burning coals in the upper part. Ironstone courses are most plentiful in the middle and lower part, where also lie the "muscle bands," of which regular layers have been some time known in the coal field of Yorkshire, and are not without representation in that of Newcastle. This latter analogy is very remarkable, and the occurrence of these muscle bands is almost a peculiar character of the great Northern coal fields.

A comparison of the details of these coal fields would afford an excellent test of the points of analogy, and the extent of variation, which may be expected to occur in neighbouring carboniferous deposits.

The broadest part of the whole tract is between Halifax and Ferrybridge, or rather Went Bridge, in Yorkshire, where the dip is moderate and regularly to the South-East, the stratification not subject to more than usual disturbance, and the greater part of the coal seams worked to supply the wide-spreading industry of the West Riding. The whole coal system of the Country is thus unfolded, all its products are employed, and the ranges of most of the beds perfectly known. In addition it happens fortunately, that not only the millstone grit is remarkably distinct, and the series immediately above it, the lowest part of "the coal field," unusually developed, and rich in organic remains, both animal and vegetable, but the uppermost part of the system beneath the magnesian limestone is also fully exhibited. This is therefore on all accounts the most complete coal field in the Island, and the fittest to serve as a type of comparison for the others.

Yorkshire coal field.

The following mode of classification of the Yorkshire coal seams will be found very natural and convenient, for the several groups of coals here assumed have certain collective characters derived from this combination, and occupy distinguishable ranges of mostly argillaceous country between lines of sandstone hills.

Magnesian limestone unconformedly covers the coal seams.

Upper coals ...	Shales and Badsworth coal. Ackworth rock. Wragby and Sharleston coals.

Red rock of Woolley, Hooton—Roberts, &c.

Middle coals ..	Furnace coals.	Barnsley thick coal.
	Intermediate coals.	Rock of Horbury. Middle coals.
	Ironstone coals.	Silkstone beds. Low Mow and Flockton coals.

Flagstone rock of Woodhouse, Bradford, Elland, Peniston, &c.

Lower coals. ..	Shales and ganister stone. Coals. Shales and ganister stone. Coal. Shales, &c.

Millstone grit lies below the "coal series."

Lower or ganister coal series.

The lowest portion of the Yorkshire coal strata resting upon the millstone grit produces comparatively but a small quantity of coal, and this not in general of a good quality. But no part of the coal field is more curious in its Geological relations, or more worthy of close study by those who desire to penetrate into the history of the production of coal. We may define this lowest coal series very simply by saying, that it is included between the millstone grit beneath and the flagstone rock above, having a thickness of about 120 or 150 yards, and enclosing near the bottom two thin seams of coal, one or both of them workable, and several other layers scattered through its mass too thin to be worth working.

The most regular and continuous of all these coal seams, reaches in a few places the thickness of 27 or 30 inches, but is generally only about 16 inches, and is worked at Yeadon, Rawdon, and Horsforth, near Leeds; at Baildon and Heaton, near Bradford; at Catharine Slack and Swan Banks, near Halifax; at Bull Houses, near Penistone; and at several points West of Sheffield. It would have been impossible to have traced so thin a seam of coal along so extensive a range without some peculiar facilities, some points of reference more distinct than the varying quality of the coal, and the still more irregular fluctuations of the sandstones and shales. This coal seam is covered by a "roof" unlike that of any other coal bed above the mountain limestone in the British Islands; for instead of containing only the remains of plants or fresh-water shells, it is filled with a considerable diversity of *marine shells* belonging to the genera *pecten* and *ammonites*, and in one locality specimens of *orthoceras*. *Posidonia* and scaly fishes have been obtained from certain nodular concretions, called "baum pots," lying in it. The uniform occurrence of these pectens and ammonites, through so wide a range, over one particular thin bed of coal, and in no other part of the coal strata, is one of the most curious phenomena yet observed concerning the distribution of organic remains, and will undoubtedly be found of the highest importance in all inferences concerning the circumstances which attended the production of coal.

In this part of the coal system we may observe, besides the very remarkable layer of marine shells, several occurrences of a peculiarly hard silicious sandstone, called galliard, ganister, seatstone, &c., which, in fact, is the same thing as the crowstone of the mountain limestone series in Swaledale. This stone in some cases forms the floor or sill of the coal, a circumstance never observed in the upper coal strata, amongst which, indeed, galliard never occurs in its true character. Hence this whole group of strata may be appropriately termed the ganister coal series.

The ammonites and pectens which lie above one of the seams of coal, and still more the orthocerata which sometimes accompany them, are remarkably analogous, and perhaps in part identical with fossils of the mountain limestone. The galliard is likewise to be compared with similar stones in the mountain limestone series, and therefore the ganister coal series might be with much propriety associated with the upper mountain limestone series of the Penine chain, or with the millstone grit series of Derbyshire, and thus the flagstone would appear to be the lower limit of the true coal measures. But an examination of the neighbourhood of Halifax has shown another order of phenomena and another set of shells, which connect this same series with the upper or true coal measures. In the upper coal series of Northumberland, Derbyshire, and Yorkshire, are several layers of bivalve shells, commonly referred to the genus unio, from which the fresh-water origin of these coal deposits has been inferred. In the midst of this series of ganister coals two layers of these shells occur, one of them about the middle of the series, considerably *above the pecten coal*, the other near the bottom, and considerably *below that coal*.

No shells of this kind have ever been met with in the mountain limestone group which there is every reason to consider as of decidedly marine origin; not one of all the zoophytic, testaceous, or crustaceous reliquiæ of this limestone has ever been found in the upper coal series. This opposition of zoological characters would appear to be fully explained if the coal deposits were admitted to have been accumulated in fresh water. And this opinion is perhaps generally adopted.

We find then in the lowest coal series, which is placed on the line of transition between the marine and fresh-water deposits, zoological and mineralogical characters common to both. Examined in detail we find these characters not mixed, but alternating in such a manner as if there had been one periodical return of the marine element into its ancient receptacle, after that had been for some time occupied by fresh water and its few inhabitants. The effects of this irruption having as it were worn out, the zoological characters of fresh-water deposits are again manifested at intervals, in the upper system of coal beds, till this series is finally ended, and marine exuviæ reappear in the magnesian limestone.

If, from whatever cause, we could witness the effects of a general irruption of sea-water into a modern lake of great extent and considerable depth, it is probable that the resulting phenomenon would be perfectly analogous in kind to those described above. But this irruption of the ancient ocean into the coal basin of Yorkshire, was probably not produced by any violent convulsion *in that basin*, (for there is no unconformity between the supposed fresh-water and supposed marine deposits,) but by some disturbing causes originating *at a distance*. As the elevation of the Western Alps has probably occasioned the dispersion of boulders in Dauphiné and Provence, and the uplifting of the Scandinavian Alps has been followed by diluvial currents in Germany without much affecting the position of the strata in those Countries, so may the Yorkshire coal district have felt the transient shock of some distant convulsion. The periodical revolution in the nature of the waters which operated the deposition of the lowest coal strata in Yorkshire, bears so remarkable an analogy to some of the phenomena of the marino-lacustrine tertiary deposits, that the same principles will probably serve as a basis for the explanation of both cases.

In both cases we have a *decidedly marine* deposit below, and a *decidedly fresh-water deposit* above; the intermediate ground is not exactly neutral, but sometimes shows gradations from one to the other, and sometimes periodical alternations, accompanied however by so entire a parallelism of strata, that in seeking for the cause of these changes, we are compelled to have recourse to agency at a distance, to the blocking up of the outlet of an estuary, or to irruptions of the sea, arising from subterranean disturbances in a different quarter.

The lower coal series of Yorkshire is terminated above by a thick deposit of sandstone, which is never so coarse as the millstone grit, and generally appears to be more argillaceous. Its degree of consolidation varies according to localities and circumstances of drainage, but there is hardly a single point in its whole range, from the vicinity of Leeds to beyond Sheffield, where the title of flagstone rock is not eminently applicable to it. Along this whole range, by the valley of the Aire to Bradford, over the hills to Halifax and Elland on the Calder, and by Huddersfield and Peniston to Sheffield, it is the grand repository from which the immense demand for Yorkshire flagstone, both within the County and for all the Eastern and Southern coasts, is supplied. In particular situations, especially near the surface, it is often so thinly laminated as to produce good roofing slate, while the deeper parts of the quarries produce capital building stone. This diversity of qualities is consistent with great simplicity in structure. It is a finely laminated stone, having its beds in general very parallel, and thus, according as the whole mass of a bed is employed, or as it is split into portions or resolved into its component plates by the action of natural causes, wallstone, flagstone, and slate result. The micaceous surfaces of every common flagstone immediately disclose to us the cause of its natural partings; and further examination shows the whole thickness to be divided by other layers of mica into a number of parallel plates, which sometimes separate by the mere influence of the air, but generally, after being once dried, cohere together with considerable force. In this case it is difficult to say what technical use should be made of the term *strata*, which may with equal verbal accuracy be applied to the micaceous laminæ, or the plates of slate or flagstone to the beds of the rock singly, or the whole united mass of sandstone layers. In Mr. Smith's nomenclature the whole flagstone rock is one stratum. However this may be determined, there can be no doubt that even the least and thinnest of the micaceous layers owes its origin to a particular operation of water, and required the intervention of a certain interval of time, to permit the separation of the grains of sand and the scales of mica.

Flagstone rock.

It has been said above that the micaceous laminæ, plates of flagstone and beds of the rock, were all parallel. This is usually and very exactly the case, but in certain places while the beds and flagstones, which are only *lesser beds*, are parallel to one another, the *micaceous* layers which make up the mass of the beds, *form considerable angles with the plane of their surfaces*.

Thus in plate i. fig. 2 the upper part of the diagram shows all the partings parallel; and this is the ordinary case of the flagstone rock, but in the lower part of the diagram the micaceous laminæ are inclined to the other surfaces of parting.

Such flagstones have generally a rough or ragged surface, and are much liable to scale off in irregular "shells," which disfigure the beauty of the stone. This oblique lamination of the mica strongly reminds us of the "false bedding" of millstone grit, and of the shelly beds of oolite, which probably were formed in slightly agitated water.

The surface of the rougher flagstone beds is also liable to other peculiarities, as waves or undulations, like the ripple marks on a sandy shore, little hard knobs on one face corresponding to depressions on another, and sometimes a vermicular marking, which more than any thing else resembles the arrangement which semi-fluid matter assumes on smooth surfaces of stone, when these, after having been laid together, are forcibly pulled asunder.

The micaceous layers are not unfrequently coloured with a mixture of carbonaceous particles.

Vegetable remains lie in this rock in many places, and in considerable plenty. Equisetaceous plants in particular are abundant in it about Leeds, accompanied by trihedral fruits. Lepidodendra, sigillaria, &c. occur in it less plentifully.

In general, what is said of the accidents of structure of the flagstone rock of the Yorkshire coal fields applies to the laminated sandstone rocks of the mountain limestone, and even to the analogous but more recent layers in the oolitic coal system on the coast of Yorkshire.

Middle coal ies.

This is the most valuable part of the Yorkshire coal field, and includes as many as ten workable seams of coal, of various quality, with several layers of ironstone bands, one of them full of fresh-water shells. The flagstone rocks define the series below, and the coarse, often iron-stained sandstones of Newmiller Dam, Woolley Edge, and Rawmarsh form its upper boundary.

It may be convenient to divide this great group into three portions, thus:—

	Red rock of Woolley Edge.
	Furnace coals of Barnsley, &c., including the eight or ten feet seam.
	Rock of Horbury and Wentworth House.
	Swift-burning coals of Middleton, Dewsbury, &c., with bands of "muscles."
Ironstone coals.	Bituminous coals of Silkstone, Low Moor, and Flockton.
	Flagstone rocks beneath.

Upper coal series.

Upon the coarse rocks of Woolley Edge lies the upper series of coal measures in Yorkshire, which exhibits alternations of sandstones and shales very much like those of the middle and lower groups, but without the layers of muscles, and generally without the presence of productive ironstone bands. The reliquiæ of plants are more rare in these strata, and the coal is of inferior quality, more earthy and less bituminous. Two considerable seams of coal near the bottom, worked at Wragby, Sharleston, &c., and one or two thinner seams nearer the top of this series, appear to be the last of the formation, and are unconformably covered, as are all the others in their turn, by the magnesian limestone, against which deposit the line of separation is hard and distinct.

Comparisons with other coal fields.

We are now in a condition to institute a comparison between the results of observation on the strata of the Yorkshire coal fields, and those which had been drawn from similar researches on the other coal districts of Britain and the Continent. For this purpose it will be of little use to take into account the number or thickness, or chemical quality of the beds of coal, since these characters, however important locally, are too variable to guide us across even the whole extent of a single coal basin, and vanish altogether upon distant points. We must, therefore, restrict ourselves to the most general divisions of the carboniferous series, and compare the coal fields with reference to the strata which separate the coal from the mountain limestone beneath, the occurrence of bands of ironstone and muscle-shells, the nature of the rocks and shales, and the distribution of organic remains.

The great Northern coal fields.

The characters of the Yorkshire coal fields are recognised in their continuation Southward through Derbyshire and Nottinghamshire. The same ranges of millstone grit and shales lie beneath, similar rocks of hard ganister lie in the lower part, with a similar belt of useful flagstone. The lower part of the series contains the most bituminous coals, and the most abundant course of ironstone, some of which contain fresh-water shells, and the upper parts yield similar swift-burning thick coals.

The Lancashire and Cheshire coal fields are certainly portions of this great Northern system, separated in consequence of the subsequent uplifting of the mountain range of the Penine Alps. The same *ganister* and flagstone occurs near Stayley Bridge, resting in the same order of succession upon the same millstone grits, and though the broken condition of the coal fields on the West of the summit ridge scarcely allows of the same accurate delineation of the courses of the coal beds, enough is already known to justify the reunion of the coal-deposits on both sides of the Penine Alps.

Notwithstanding the great interval in the superficial range of the coal strata between Aberford and Cockfield Fell, the series in the Durham and Newcastle coal fields is very analogous to that of Yorkshire.

But hitherto, no layer of marine shells has been noticed in the lower part of the Newcastle coal fields, and, therefore, the inference of alternate inundations of the sea and fresh water cannot be applied to this coal field, though the general conclusion of marine deposits below, and freshwater deposits above, remains unimpaired.

Fresh-water shells, accompanied by nodular ironstones, and numerous reliquiæ of equisetiform and filicoid plants occur *without limestone* beds in the coal fields of Clackmannanshire, Falkirk, and St. Andrew's, but most of the Scotch coal fields, like that of the North and West of Northumberland, are formed by a developement of the carboniferous limestone group of Yorkshire and Durham, and contain marine shells.

Great South Wales coal field.

The immense coal basin of South Wales (which is, in fact, as Mr. Conybeare has shown, divided into two parallel basins by a longitudinal axis of elevation,) presents so many features in common with the detached coal tracts of Dean Forest, Kingswood, and the valleys of Somersetshire, that for our present purpose we may conveniently group them together.

The total thickness of the coal strata is very great, for in the deepest part of the basin near Neath, the lowest strata of coal are nearly 700 fathoms below the outcrop of some of the superior strata in the more hilly parts of this district. There are (according to Mr. Martin) 23 beds of workable coal, making altogether 95 feet, 12 of them from 3 to 9 feet thick, 11 from 18 inches to 3 feet; besides numerous other beds from 6 to 18 inches thick.

The coal on the North-Eastern side of the basin is of a coking quality, excellent for the iron manufacture; on the North-Western it contains little or no bitumen,

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being what is called stone coal or culm; on the South side, from Pontipool to Caermarthen Bay, it is of a bituminous or binding quality. The cause of these extreme differences in the quality of the coal is not known, and, indeed, the subject of the varying quality of a coal bed has never yet been adequately investigated. Many analogous though less striking examples are familiar to every coal-worker of sufficient observation and experience.

The numerous excavations along the Northern border of the South Wales coal district, for the purposes of the iron manufacture, present us with a complete section of the middle and lower parts of the coal measures, the limestone series beneath, and the general base of old red sandstone.

The lowest part of the coal measures consists of alternations of sandstone and shale, without coal; the lowest bed (in the place of millstone grit) being a conglomerate sandstone. Above this series, two or three thin seams of coal occur, and these are followed by an argillaceous series, containing many thick and valuable beds of coal, and sixteen layers of ironstone in thin beds and nodules. Whether the ironstone nodules contain shells has not (it is believed) been stated, but the general analogy of arrangement of the coals and ironstones to that which has been described in the Northern coal fields, will be immediately obvious.

It appears that the upper part of the coal strata is characterised by the predominance of coarse sandstone with carbonaceous specks, like that called Penant in Somersetshire, and that a considerable thickness of such rocks intervenes between the upper and lower coal seams.

This sandstone is occasionally highly micaceous and fissile, and yields very good flagstone and even roofing slate.

The coal strata of this entirely insulated coal field rest occasionally upon a coarse sandstone like millstone grit, but the general floor is mountain limestone, which contains a layer of oxide of iron, in such plenty as to feed the iron furnaces. The coal seams, seventeen in number, contain about thirty-seven feet in thickness of clear coal, which is mostly bituminous and swift-burning, but in the lower seams partakes more of a coking quality. The ironstone nodules which lie in the shales are of little importance; the sandstones are mostly in the lower part of the section.

The neighbouring coal field of Newent rests on transition strata along the Southern and Western edges, and on old red sandstone along the North-Western. (*Geological Proceedings*, 1833.)

The broken coal deposits of South Gloucestershire and Somersetshire agree in being begirt by an irregular belt of mountain limestone and old red sandstone, and occasional patches of sandstones occupying the place of millstone grit. The irregular undulations of the strata in this district, and their concealment through extensive tracts by overlying deposits, present formidable obstacles to the attempt to trace the series of beds which constitute this coal field.

Mr. Conybeare supposes that it may contain as many as fifty or sixty coal seams, most of them very thin, hardly any of them exceeding one yard, and, therefore, unless of good quality, in a country at some distance from more productive collieries, and aided by the improvements of modern machinery, scarcely capable of being worked to profit.

As in the South Wales coal field, shale predominates in the lower, and the Penant grit rock in the middle part of the series: the shale beds frequently contain beautiful impressions of ferns and muscle-shells. (*Geology of England and Wales.*)

The Somersetshire coal fields have been admirably illustrated by Dr. Buckland and the Rev. Wm. Conybeare. (*Geological Transactions.*)

Flintshire.

The well-connected coal basin of Flintshire, in the basis of which the estuary of the Dee is formed, extends from North to South somewhat more than 30 miles, from Llanassa to near Oswestry in Shropshire, forming an exterior belt coextensive with the range of the mountain limestone from the North of the Clwyd; where that limestone is partially interrupted by the mountain of Selattyn, the coal shales rest immediately on the transition slate of that mountain. The coal strata dip generally Eastward, and form in the Northern part a trough beneath the estuary of the Dee, and rise again on the Eastern side of that estuary in the district called Wirral, from whence, sinking again beneath the red sandstone, along the course of the Mersey, they may possibly be prolonged to the South Lancashire coal beds, near Prescot.

Plain of Shrewsbury.

This coal basin in Flintshire commences with beds of shale and sandstone, answering in position and character to the shale and millstone grit of Derbyshire. The coal is of various thickness from three-quarters to five yards, and consists of the common cannel and peacock varieties. (*Geology of England and Wales.*)

The broken patches of coal strata which lie on the South of the Vale of Severn near Shrewsbury, are arranged according to the irregular positions of the transition rocks, which in the Stipperstones, Longmynd, Wenlock Edge, the Wrekin, Caer Caradoc, &c., extend themselves in a curve far to the East of the great body of the slate rocks. The true relations of the coal strata to the transition ranges, between whose projections they are enclosed, have recently been examined by Mr. Murchison, and connected with general views of the dislocations along the line of the upper slate formations. It appears that the carboniferous strata repose on the edges of the slates, and dip towards a common centre under the new red sandstone. At Pitchford the whole carboniferous series is represented by a bituminous breccia, of a few feet in thickness. Three thin beds of coal are, for the most part, observable, and the deposit is distinguished by an included band of limestone similar in mineral aspect to the lacustrine limestones of Central France, and containing minute planorbes very similar to those mentioned above from the middle coal seams of Yorkshire and Northumberland. (*Geological Proceedings*, 1833.)

Coalbrook Dale.

On the East side of the transition ranges of the Wrekin and Wenlock Edge lies the coal field of Coalbrook Dale, which contains at the bottom a sandstone called the little flint, of which the lower part abounds in pebbles, and is, in fact, a millstone grit. The ironstones, which lie in fives or six layers, are balls or broad flat masses, like those in Yorkshire, &c. and contain abundance of the same vegetable impressions, and a few shells; those which we have examined (belonging to the marine genera orbicula, conularia, ammonites) indicate the propriety of an inquiry into the *distribution of the molluscous remains* for comparison with the results of this investigation in Yorkshire.

The coal beds are mostly thin; the ten uppermost

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are too sulphureous for other uses than lime-burning, and are called stinkers; twelve beds of good coal, in all twenty-five feet thick, the thickest being five feet, succeed, and the lowest bed of the whole formation, eight inches thick, is sulphureous. The best coal of this coal field usually presents a mixture of slate coal and pitch coal, rarely of cannel coal; none of it possesses the property of coking.

The sandstones of this coal tract are usually fine-grained and micaceous, and speckled with fragments of coal; but some of them are coarse-grained, and two remarkably so. The sandstones generally contain vegetable impressions, but never form the roof of the coal, which is invariably shale. Two beds of coarse sandstone, fifteen and a half feet in thickness, are entirely penetrated by petroleum, which flows out perpetually in the *tar spring* at Coalport. This bitumen is likewise found in the basses or indurated slate clay. These details are chiefly derived from observations at Madely colliery, where a pit, sunk to the depth of 729 feet, passes through all the strata, eighty-six in number, which constitute the coal formation.

This coal field rests at Steeraway, and near Little Wenlock, on a thin band of limestone, which Mr. Murchison has recently proved by its fossils to be mountain limestone, whilst in the contiguous extension of this field, the carboniferous strata overlie, *unconformably*, various members of the transition series, with one of which, the transition limestone of Wenlock Edge, they are brought into *conformable* apposition at Lincoln hill.

Clee Hills, &c.

The divided coal-basin of the Clee Hills is elevated upon the mountain limestone and old red sandstone of Corvedale, and contains several seams of coal and layers of ironstone, much confused in their arrangement by interpositions of basaltic dykes and overlying masses, and resting below on a hard conglomerate sandstone. This interesting country has been recently examined by Mr. Murchison. On three sides of the Brown Clee Hill, the coal strata rest on old red sandstone, which to the West is a coarse conglomerate; but on the fourth or South-Eastern side, there is interposed between the old red and the lower coal grits, a thin zone of mountain limestone. (*Geological Proceedings*, 1833.)

Trap rocks confuse the arrangement of the coal strata in the whole space between Corvedale and the Severn, which includes the narrow coal field of Billingsley and Burdley, which has also attracted the labours of the same Geologist.

Central coal fields.

The double coal field which surrounds Ashby de la Zouch is based on mountain limestone, which, like some portions of that of Derbyshire, contains abundance of magnesia; there is, however, no particular correspondence to be remarked in other respects; no millstone grit has been recognised, no flagstone, nor conchiferous ironstone. Amongst the seams of coal is one of the variety called cannel, and another from seventeen to twenty-one feet in thickness. (*Geology of England and Wales.*)

The strata of the Warwickshire coal field are based upon a compact cherty sandstone, called by Mr. Conybeare "millstone grit," but no limestone appears round the escarpment of this narrow coal tract. The seams of coal are liable to great changes of thickness in consequence of the occasional attenuation of the interposed strata of shales.

The coal field of Dudley, Bilston, and Cannock Chase agrees in part with that of Coalbrook Dale, but differs from all the others by the character of the subjacent limestone, for this is generally admitted to belong to the transition system. The coal measures are supposed by modern writers to be unconformed to the limestone, but their dips correspond in direction though not in degree. The limestone is uplifted into a saddle-shaped or anticlinal ridge; the coal strata rest upon its slopes, and are covered by the new red sandstone formation.

There is no millstone grit, nor any flagstone, and (as usually among the central coal basins) the strata are mostly argillaceous. Ironstone courses occur in several parts of the series, but the only valuable ones are near the bottom. The seams of coal are numerous, but only the lower ones are workable.* They are of various thicknesses from two to ten yards, or even fifteen yards.

It is not, however, to be supposed that these enormously thick seams are single beds of coal; they are in fact composed of several beds locally accumulated together, with certain partings, which in other places swell out into considerable thicknesses of shale. Thus the upper part of the ten-yard coal separates from the rest of the beds, and under the title of the "flying reed," becomes a totally distinct bed in the Northern part of the coal tract.

Ireland.

The coal fields of Ireland occupy very large tracts in the centre of that country, and are upon the whole very analogous in general mineral characters and organic contents to those of England. The same absence of limestone, the same kind of succession of sandstones and shales is remarked in them. Carbonaceous or stone coal, like that of South Wales, abounds in the Leinster and Munster districts; bituminous coal in Connaught and Ulster. The Munster coal district is stated by Mr. Griffith to be of greater extent than any English coal field. In this tract (County of Cork) Mr. Weaver supposes certain anthracitic beds to be interposed in greywacke, and to be subject to all its flexures, but certainly the greater part of the coals of Cork and Limerick are of the same age as the English coals. At Ballycastle the coal is found in connection with basalt. (See Conybeare, *Geology of England and Wales.*)

General View of Circumstances under which the Coal Beds were deposited.

I. Few subjects in Geology have been examined under more various points of view than the question of the origin of coal, and the circumstances under which it was deposited. We may wonder at the philosophical blindness which would permit in the last century protracted disputes concerning the vegetable origin of coal, when so many thousand plants converted into that substance were found in the shales and sandstones of every coal district. But in those days this kind of evidence was so little understood, that the inimitable impressions of ferns and other plants from which we are now accustomed to reason concerning the climate and other conditions of the ancient world, were not even admitted to be reliquiæ of the vegetable kingdom.

There is no necessity to enlarge upon the proofs of the origin of coal from vegetables, drawn from an examination of its chemical constitution as compared with vegetable products, and the composition of the ligneous parts of plants, and from the unanswerable identity of the carbonaceous substance, into which a vast multitude of

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fossil plants have been converted. The chemical constitution of this carbonaceous product of the individual vegetables, is exactly analogous to the chemical constitution of coal; and it is quite probable that hereafter the reason of the variations to which both are subject, whether dependent on the original nature of the plant or produced by subsequent operations, will be as apparent as that of the general agreement arising from a common vegetable origin. (For some remarks on a part of this subject see ch. i. p. 547.)

II. Admitting then the vegetable origin of coal, the next question relates to the situation where the plants grew from which the vast mass of the coal seams was derived.

Many of the plants accompanying coal are of unknown types, and some are too imperfect to permit any botanical deductions; but the researches of Naturalists have nevertheless been successful in determining some general characters of this ancient flora.

The greater number of these plants were decidedly terrestrial.

They appear to be most analogous to tropical tribes of vascular, cryptogamic, and coniferous plants.

They grew then on the land, and it is probable from M. Brongniart's researches, that this land was in a high degree subject to heat and moisture, more so than perhaps even the coasts and islands of tropical seas, to the flora of which situations the coal plants present most remarkable general approximations. (See p. 603.)

III. We may now venture upon the main part of the inquiry which relates to the origin of coal, *viz.* whether the plants from which coal was produced *grew in their present situations*, and were there submerged and buried beneath marine or fluviatile deposits, or were swept down to their present repositories *from distant situations* by land floods and other causes. To guide us in this inquiry the following data may be premised:

1. The *generally uniform*, or *gradually varying*, thickness of the several coal seams over a very large area.

2. The broken and fragmentary condition and confused intermixture of the plants which accompany coal strata, and their being generally *without roots*.

3. The occurrence of the *same species* of plants in shales, ironstones, and sandstones.

4. The occasional vertical position of *broken stems* of large trees.

5. The *parallelism* or conformity of the several beds of coal.

6. The extreme differences in the thickness of the several seams, and the occurrence of many *very thin plates of coal* through many of the coal shales.

Peat bogs

De Luc and several eminent Geologists, and lately M. Adolphe Brongniart, have supposed coal beds to have been originally a sort of peat bogs, or masses of vegetable reliquiæ accumulated round the place of their growth, upon which other vegetables grew, and that subsequently these tracts of country during some extensive convulsions subsided below their former level, and were covered by various mechanical deposits. This hypothesis seems to have been suggested by the seeming analogy in some respects between the chemical changes which have happened to the vegetable matter of peat bogs and of coal, by the occurrence of stems of plants vertically in the coal strata, and by the supposed difficulty of otherwise explaining the acknowledged regularity of the coal beds.

These circumstances may appear to favour the hypothesis of De Luc, but they cannot make us overlook very serious objections to it.

The formation of *peat bogs* is, as far as we know, not of the kind here supposed. It is not by fragments of trees and herbaceous plants accumulated round the place of their growth, but of a variety of successively dying mosses and other moisture-loving plants that the peat bogs *grow up* to the extent which they occupy on the high cold hills of the North of England.

Subterranean forests.

There is, however, another kind of vegetable accumulation which may be thought to throw more light on the origin of coal. The *turf or peat moors*, as they are called in the North of England, which occur in low ground toward the estuaries of rivers, and along the margin of the sea, in many parts of England, contain a mass of vegetable matter, composed of mosses and other humid plants, roots of ling, &c. and envelope trunks of trees, sometimes prostrated in particular directions, apparently cut by art or decayed by time. In some places are oak, in others birch or fir, according, as Mr. William Smith has observed, to the nature of the soil below, which is sand, marl, or clay. With them often lie the remains of terrestrial quadrupeds, land shells, &c.

The marls sometimes contain fresh-water shells, but never marine exuviæ. In most places these accumulations of vegetable reliquiæ are below the level of the sea, and covered by *various alternations* of mechanical deposits, sands, and clays brought down by the rivers or deposited by the tide.

These phenomena appear to admit of an easy explanation, if we allow that the relative level of the sea and land has been locally subject to variation, and thus the drainage of the country deranged.

The greatest part of the vegetable mass grew in its present situation; it was a humid forest where the leaves and branches of the trees, mingling with the herbaceous covering at their base, formed an extensive carbonaceous mass, which enveloped the trees when they fell by any great violence of wind or flood, perished by natural decay near the base, or yielded to the axe of the old inhabitant. In cases where the situation was elevated, or otherwise removed from the action of the tide, the ancient forest has been sometimes converted to a lake, or overwhelmed with the ruins brought by a land-flood. Along the side of great rivers, where the level was permanently below the floods or tides, many successions of sandy and argillaceous deposits have taken place, and sometimes a second accumulation of vegetables; and thus the whole alluvial *sediment and subterranean forest* resembles in some important respects the alternations of earthy deposits and carbonaceous layers which compose the ancient coal strata.

Lake deposits.

We have, however, not yet exhausted the heads of the subject of the agglomeration of vegetable reliquiæ. In many situations in England, as in Holderness, (*Geology of Yorkshire*,) they have been swept down from the land, and accumulated on the beds of lakes in a pretty regular stratum of partly decomposed leaves and herbs, with branches of hazel bushes, nuts, &c. and fragments of larger trees. Over them the lake has since diffused, in regular layers, the sediment brought into it by the streams and floods, with the shells which lived in the waters.

River deposits.

The Mississippi and other great rivers of the World whose banks are clothed with immense primeval forests,

where from age to age the trees as they fall are rolled away by the periodical inundations, deposit in their wide mouths *alternate* and repeated layers of vegetable and earthy matter, and thus present us with another analogy to the coal strata more exact in detail than any of the preceding, and more justly comparable in extent of effect.

To what distance in the sea trees may be rolled by the mighty continental floods, those who have been accustomed only to contemplate the trifling streams of England, can have no proper idea; but the navigator who at the distance of two or three hundred miles recognises in the Atlantic the last effort of the current of the Amazons, or in the Bay of Bengal observes the immense accumulations of earthy sediment transported by the gentler waters of the Ganges, will readily admit that the estuary deposits from such rivers may exceed the area of the most extensive of our coal basins. (See Lyell's *Geology*.)

Effects of higher temperature.

If we are right in the inference that the ancient flora which lies buried in our coal tracts was the growth of even more than tropical heat and moisture, we may readily conceive how these circumstances, joined to the certain fact that the land was then of far more limited surface, would also explain the *greater amount* of both the organic and inorganic depositions from the ancient drainage of the earth. For a higher temperature of the air and earth, accompanied by more abundant moisture, would naturally be followed by more luxuriant vegetation, more abundant precipitation of rain, greater and stronger rivers, and more violently excited floods. As the rich vegetation and atmospheric storms and destructive floods of the tropical region exceed those of our colder latitudes, so would the effects of the ancient floods in still hotter climates surpass the most powerful results of the present combination of agents.

It is possible that the effect may have been heightened by some essential difference in the constitution of the atmosphere; (M. Brongniart supposes by a large proportion of carbonic acid;) but without at present entering these fields of hypothesis, the botanic characters of the fossil flora appear to warrant the conclusion above stated.

From this short review of the operations now in progress, by which a part of the decayed vegetable covering of the earth is accumulated in peat bogs, lakes, estuaries, and the sea, we perceive clearly that if the production of coal be not now actually in progress in certain situations, deposits of carbonaceous substances happen under circumstances which will greatly contribute to correct and simplify our notions of the origin of that combustible.

Coal formed in various situations.

Until all the circumstances which characterise the different coal basins have been very fully investigated, it will be hazardous to decide *generally* against any hypothesis advanced to explain the deposition of coal, which proceeds upon observation of the accumulations of vegetable matter now in operation. It may hereafter appear that the vegetables of some coal basins grew where their remains are now carbonized, according to M. Brongniart's notion; that other coal beds arose from trees and plants, swept down from the land into fresh-water lakes; that others were formed in estuaries alternately traversed by floods from the land and tides from the sea; and that some were transported far into the deep and tranquil ocean.

But all the weight of observation yet made is decidedly in favour of the opinion that the *greater portion of all the carbonaceous* deposits were swept down from the places where they grew on the land, to ancient lakes, estuaries, and seas; and, indeed, it is perhaps not yet made *probable* that any continuous bed of coal has been produced otherwise.

Generally not where the plants grew.

For De Luc's notion of the plants growing in the very spot where they have been converted to coal seems altogether inapplicable to cases where many layers of coal alternate with many of sandstones, shales, ironstones, &c. For this could only have happened, according to that notion, in consequence of at least as many subsidences and subsequent elevations of the same tract of strata, as there are coal seams in it; and when in addition we take into account the perfect parallelism of the strata indicating no disturbance, the thin laminæ of coal which sometimes occur in the shales, the local divisions of the seams of coal, and the quantity of land plants lodged in the separating strata, we shall be compelled to limit to very few cases an hypothesis which involves such gratuitous difficulties.

1. On the contrary, these very circumstances are exactly such as must necessarily be occasioned by the effects of periodical floods operating through a long succession of time upon a well-wooded country. They would transport at intervals vast quantities of vegetable and mineral matter into the lowest receptacles of water. There the mingled mass would be *sorted by the waters*, according to bulk and specific gravity, as we observe every day in lakes and on the sea-shore, an effect which most probably would be much heightened by the unequal velocity with which masses of such unequal bulk and gravity would be originally transported by the current. They would be deposited in distinct layers, of which the *most regular and uniform* would be the layers of plants, because these are more different both as to bulk and specific gravity from the other materials brought along by the stream, than are these materials among one another; a fact *remarkably conformable to observation*.

2. But though the greater mass of the plants would be thus separated from the earthy sediment, there would probably be some portion unavoidably entangled therewith and deposited with them, and thus the sandstones and shale are found to contain in confused admixture a considerable number of plants.

3. The trees thus transported by the floods might for the most part not have been uprooted; they would also in their course be broken and mutilated, and mostly deprived of branches and leaves, exactly as we find them in the coal strata.

4. In the various eddies of the waters under which the sediment fell, some trees might be reared upright, and others might and indeed would float with the heaviest end downward, and be kept in that posture by a sudden and great accumulation of sediment, and thus we seem to have a natural explanation of the occasionally vertical position of trunks of sigillariæ, and equisetaceæ in sandstone. In shale deposited more tranquilly, this fact has never or most rarely been noticed.

5. Successive operations of this kind would equalize the results over a large area, and produce a remarkably general parallelism of strata in the *same basin*.

6. According to the condition of the currents, the accumulations at any given time, or for any period, might be in one part wholly vegetable, in another wholly earthy, or of alternate quality, and thus the occasional

deadness of a part of a coal tract usually productive, the division of a coal seam into its constituent portions, and the partings of a coal bed appear all perfectly natural consequences of the same simple cause.

7. It is probable that in lakes which receive floods overcharged with sediment, and which in consequence are frequently muddy, few kinds of mollusca, or fishes, or other animals would live, and that the molluscous remains would be such only as belonged to bivalves, like unio and anodon, or univalves, like paludina, which never come to the surface for respiration, but remain at the bottom of the waters. The shells found in coal tracts, supposed to be of fresh-water origin, are principally uniones and anodonta.

8. It is also probable, for the same reason, that only a small number of the animals or plants actually existing in the sea at any one time would be found within the area of a very muddy estuary, and thus we see the reason why the coal basins which contain no fresh-water shells, and are from other circumstances presumed to be of marine origin, are generally devoid of animal remains, except in the calcareous layers or nodules which may occur in them. These calcareous deposits evidently mark periods during which the chemical precipitations from the sea were little or not at all troubled by the mechanical aggregations from the floods of the land.

9. As many basins of fresh water, estuaries, or seas, as received the vegetables and sediment brought down by the floods, so many distinct series of carbonaceous and argillo-arenaceous deposits would be produced;—there would be no *particular agreement* between them in the number, thickness, and quality and arrangement of the coal seams, rocks, or shales, or ironstone, but a *general agreement*, depending on the common physical conditions of the region. But in the *same basin*, even over very large areas, there would frequently occur *particular agreements*, in many respects; coals of particular quality, rocks of certain kinds, beds of ironstone, and layers of shells, may be traced over large tracts and assigned to definite places in the general section.

Convulsive Movements of the Carboniferous System.

Nothing appears more clear in Geology than that the same parts of the Globe have been alternately subject to gradual alteration, through the slow and equal action of the ordinary system of Nature, and to sudden extreme changes induced by the shorter dominion of violent disturbing forces.

The preceding descriptions sufficiently show how regular was the action of the causes which permitted the immense accumulations of chemical deposits, earthy sediment and vegetable reliquiæ, on the beds of ancient lakes or estuaries, and for how long a period this process continued, the prodigious number of alternations in the deposits sufficiently attests. It was, indeed, compared to the present state of things, a period of remarkable excitement as to the vigour of vegetation, and perhaps also as to the abundance and force of inundations; but the parts of this series, compared with one another and with analogous strata of different ages, furnish proof that the whole was the result of what may be termed the then ordinary course of natural operations.

Extent of these disturbances. But this long period appears to have come suddenly to an end, and the characteristic regularity of its deposits to have been interrupted by a general eruption of disturbing forces which have left the traces of their power and extent in all the coal fields of Europe and America. As after the deposit of the slates violent dislocations happened and were succeeded by the old red conglomerate, so after the deposit of the coal, similar and equally extensive interruptions of the planes and course of strata were followed by the analogous deposit of new red sandstone. In the course of these operations, the whole thickness of at least the stratified mass of the crust of the Globe appears to have been broken in many directions, and the divided portions raised or depressed a few inches, many yards, or hundreds of fathoms from their former level, and placed in new situations, with various angles of inclination to the horizon and in various directions. Scarcely a mine or colliery is worked in strata of this era in any part of the World which is not crossed by several faults or dislocations of this nature, and it is always found that they divide and displace in the same direction the whole series of the strata to the greatest depths which man has reached.

That these dislocations happened after the complete deposit and induration of the coal strata is evident; that they followed almost immediately, and happened nearly at the same period of time, in almost all the coal tracts, appears certain from the general fact, that the disturbances of the coal seams rarely extend into the newer strata of magnesian lime and red sandstone. There was, therefore, a general disturbing agency employed to break up the consolidated planes of the carboniferous strata; and from the occasional filling of the dislocations with basalt, various crystallized minerals, and other igneous products, no doubt can remain that the principal agent was that general source of heat which is included within our Planet, and which finds vent for its energies in different places at different times.

To particularize all, or even the most remarkable of the faults of the carboniferous systems of different Countries, and to notice all the variations of their appearance, would be entirely foreign to the intention of this treatise; such details must be sought in special descriptions of the several mining districts and coal fields. But we shall notice some of the most predominant of these dislocations, which appear to have caused the most extensive alterations in the level of the strata, and to have been most efficient in uplifting particular ranges of land, and giving new boundaries to the Ocean.

That most of the carboniferous deposits were originally limited in area, has been already stated, and therefore we must be cautious not to infer the *violent* separation of two coal tracts from the mere fact of their disunion, without reference to the connecting inferior strata. Thus the coal fields of the Forth and the Clyde were probably limited by the previous elevation of the ranges of the Grampians and the Lammermuir, and though presenting strong analogies with the Northern coal fields of Northumberland, there is no reason to believe that they were ever joined to them. Keeping this in view, and guided by a knowledge of the *characteristic points* of the several systems of strata, we shall be able with more or less facility to determine the amount of the disturbance of position induced on any given coal tract, and thus to restore in imagination the original condition of the strata. The separation of the great coal fields of Northumberland and Durham on the *one* hand from those of Yorkshire and Derbyshire on the other, appears to have been caused by a general elevation in an Eastern and Western range of the whole of the tract intervening between Wharfdale and Teesdale.

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In consequence of this and the *waste of the elevated surface*, it happens that while the lower parts of the carboniferous system are connected, the upper parts are entirely divided, and the magnesian limestone lies level on the coal of Durham and millstone grit of Nidsdale, and again covers coal in Airedale.

Penine chain.

Again, all of the great Northern carboniferous tracts are arranged with relation to an almost continuous Northern and Southern axis of elevation, from the mountains round the source of the South Tyne to Ingleborough, through Bolland forest, by Pendle hill and the Western border of Yorkshire, to the limestone district of Derbyshire, while the particular fields of Hartley Burn and Black Burton depend upon two cross lines of *dislocation* or fault, the former passing Eastward under the name of the main, or 90 fathom dyke, from near Brampton to the sea-side near Tynemouth, and depressing the strata to the North, while the latter ranges East South-East by a remarkable line of slate rocks from Kirby Lonsdale to near Grassington, and throws down to the South. The carboniferous rocks which surround the Lake mountains have certainly been affected by elevations subsequent to those which in that district followed the deposit of slate, and anterior to the deposit of the superincumbent red sandstone.

A large proportion of the mineral veins which divide the carboniferous limestone series of Aldstone Moor, and the mining dales of Durham and Yorkshire, range East and West, and may be reasonably viewed as lateral fissures proceeding from the main axis of elevation which they join nearly at right angles. The same direction at right angles to the continuation of the same principal axis of elevation is recognised in the veins of Derbyshire, some of which range to the North-East and others to the South-East, and, though with considerable variations, appears to prevail amongst the numerous faults or slips of the coal field of Yorkshire.

The great Northern and Southern axis of elevation of the carboniferous series in Derbyshire is broken across on the North, near Castleton, and appears to be terminated on the South, near Bradbourn, by great cross faults; and the whole of the coal measures of Nottinghamshire and Derbyshire, on the East, and of Staffordshire on the West of the axis, are cut off by rapid dip or sudden depression to the South. It may be conjectured that the line of this depression is prolonged beneath the red rocks of Cheshire to the estuary of the Dee, and it is, perhaps, not improbable that the red marl and sandstone which fills the drainage of the Mersey covers a large extent of depressed coal strata.

Further researches may very probably ascertain the existence of several other buried coal tracts in the midland parts of England near the detached coal fields of Leicestershire, Warwickshire, and Staffordshire.

Forest of Dean.

The Forest of Dean is a singular basin of coal strata with a belt of mountain limestone and *old* red sandstone, rising from a plain of *new* red sandstone, and looking over the vales of Wye and Usk to the similar but more extensive district of South Wales. The general line of elevation in this immense coal field is East and West, and the strata dip from both the North and the South toward the middle; but Mr. Conybeare has shown that along the middle runs an internal axis of elevation, so that the coal field is a double trough.

The elevation of the Mendip Hills, and other tracts of carboniferous limestone in Somersetshire and Gloucestershire, as well as the curious faults in the collieries near Bath and Bristol, must be referred to the same epoch, for the superior strata of red marl and the oolites are unaffected by them.

This short review shows us what extensive changes in the relative level and area of land and water were effected in these regions immediately after the deposition of the coal strata, and similar results have been obtained from researches in various parts of Scotland, Arran, and other Islands, and in the large coal tracts in Ireland.

Ardennes.

In extending our researches to foreign Countries, we must remember that the exact date of the disruption of the strata is determined by limiting the epoch between the date of the formation of the strata broken, and that of the unconformed stratum next incumbent or adjacent. Thus on passing from the Ardennes mountains to Luxembourg, we descend from the elevated slate range to a horizontal mass of new red sandstone, followed by lias and oolites; and in this case it is clear that the elevation of the Ardennes preceded the deposition of *new red sandstone*: but where that stratum is absent, (the general case along the border of these mountains,) we must have been content with inferring that the epoch of the disturbance was older than the *oolites*. On this account it is not easy to fix the date of the disturbances of the coal series of Belgium and the North of France more precisely than by saying, it was anterior to the *oolites*, since these are the oldest strata lying unconformedly over the coal.

The slips and dislocations of the carboniferous system almost invariably agree as to the direction of their slope, compared to the level of the strata with the general law stated before; (ch. i. p. 541.) but there are a few cases of such extraordinary dislocation, as at Valenciennes and in Somersetshire, that the beds of coal and accompanying strata are bent into a sigmoidal flexure, and in part turned completely upside down. Lesser cases of flexure of beds are not unfrequent.

With respect to the degree of distinctness of the planes of the slip, we may remark that this depends very much upon the consolidation of the strata divided. Thus while in limestone and solid sandstone the planes or cheeks of the slip are clearly traced, they are almost obliterated in shales and thin bedded sandstones, either by a bending at the surface of fracture, or by a filling up of the chasm irregularly with fragments from the sides. This applies even to the case of a mineral vein which crosses alternating strata of three different kinds, as in the mines of Aldstone Moor and Swaledale, where the metallic and sparry substances are crystallized in abundance in the open space between the hard cheeks of limestone and gritstone, but are far less plentiful in the obscure and contracted interval between faces of shale. In districts which appear to have been once remarkably subject to igneous eruptions, the fissures of the dislocations are often filled by basalt, both in the subjacent limestone and superior coal tracts, as in the Counties of Durham and Northumberland; but the metallic ores and spars which properly constitute a mineral vein, and which abound so much in the limestone as to give it the name of metalliferous, are very seldom found in the fissures of the coal tract.

Affinity between veins and rocks.

However it is to be explained, there certainly appears to be some affinity between the metallic matter of the vein and the nature of the strata which it traverses; and though no doubt can be entertained that the veins

are posterior to their including rocks, the frequent passage of *strings of ore* into the neighbouring strata, occasional nidiform masses, and solitary crystals of the metallic substances embedded in the interior of the rocks, besides the very remarkable examples of crystals of blende, galena, &c. in the interior of brachiopodous bivalves, seem to prove that the metallic matter has been in these cases deposited by a kind of *secretion.* Nor is this supposition, which is strongly confirmed by observations in the slate districts of Cornwall, in the least inconsistent with what is known of the diffusion of metallic substances by gradual heat much below their melting points. Breislac and Henry mention cases of the transference and collection of metallic matter, (copper) at an ordinary roasting heat, and the well-known example of titanium extricated from the melted iron of our furnaces leads to analogous conclusions. We may, therefore, very consistently maintain, that mineral veins are posterior to the strata which they divide, and yet allow that the transference of metallic substances may have been effected by the ordinary agency of heat, or the influence of electricity, so as to impregnate the strata under particular circumstances with the contents of the neighbouring veins. Such secretions of metallic substances then do not require us to admit the contradictory dogma that the veins occupying fissures are contemporaneous with the strata.

The metallic substances usually yielded by the carboniferous limestone are most of the ores of lead, zinc, and copper, with oxides and carbonate of iron, and the vein—stuff, or matrix, is calcareous spar, fluor spar, sulphate and carbonate of barytes, strontianite, quartz, &c.

Organic Remains of the Carboniferous System.

The mark * signifies that the species to which it is attached has been stated to occur in the slate system also.

PLANTS.

Family.	Name.	British Localities.	Foreign Localities.
Algæ	Equisetum infundibuliforme		Saarbruck.
	dubium	Wigan.	
	Calamites decoratus	Yorkshire	Ditto.
	Suckowii	Newcastle	Ditto, Liege, Anzin, Litry, Richmond in Virginia, Wilkesbarre, Pennsylvania.
	undulatus	Yorkshire	Radnitz in Bohemia.
	ramosus	Ditto.	Mannebach, Wettin, Germany.
	cruciatus		Litry, Saarbruck.
	Cistii		Wilkesbarre, Montrelais, Saarbruck.
	dubius	Ditto.	Zanesville in Ohio.
	cannæformis	Ditto, Newcastle	Langeac, (H. Loire,) Mons, Mannebach, Wettin, and Radnitz, in Germany.
	pachyderma		St. Etienne.
	nodosus	Newcastle	Le Lardin, Department de la Dordogne.
	approximatus		Alais, Liege, St. Etienne, &c.
	Steinhaueri	Yorkshire.	
Filices	C. Mougeotii	Edinburgh.	
	Sphænopteris furcata	Newcastle	Charleroi, Silesia, Saarbruck
	elegans		Waldenburg in Silesia.
	stricta	Ditto, Glasgow.	
	artemisiæfolia	Newcastle	
	delicatula		Saarbruck, Radnitz.
	dissecta		Montrelais, St. George Chatellaison, St. Hippolyte in the Vosges.
	linearis		Swina, in Bohemia.
	Brardii		Le Lardin.
	nervosa.		
	trifoliata	Yorkshire (Artis.)	Anzin near Valenciennes, Mons, Liege, Silesia.
	lendigera.		
	Schlottheimii		Doutweiler near Saarbruck, Waldenburg, and Breitenbach in Silesia.
	fragilis		Breitenbach.
	Hœninghausii	Newcastle	Werden.
	Dubuissonis		Montrelais
	distans		Silesia, Ilmenau.
	gracilis	Ditto.	
	Gravenhorstii		Silesia.
	Loshii	Ditto.	
	latifolia	Ditto.	
	Virletii		St. George Chatellaison.
	affinis, Lind.	Ditto.	
	bifida, Lind.	Edinburgh.	
	caudata, Lind.	Newcastle.	
	crenata, Lind.	Ditto.	
	crithmifolia, Lind.	Ditto.	
	dilatata, Lind.	Ditto.	
	Cyclopteris orbicularis		St. Etienne, Liege.
	auriculata	Yorkshire.	
	flabellata		Berghaupten.
	Several species of Cyclopteris are found at Liege.		
	Neuropteris acuminatus	Newcastle	Klein Schmalkalden.
	Villiersii		Alais. (Department du Gard.)
	Cistii		Wilkesbarre in Pennsylvania.
	rotundifolia	Yorkshire.	Mine du Plessis (Calvados.)
	Loshii	Newcastle	Anzin, Liege, Wilkesbarre.

Family.	Name.	British Localities.	Foreign Localities.
Filices	Neuropteris tenuifolia		Saarbruck, Miereschau, (Bohemia,) Waldenburg, (Silesia,) Montrelais.
	heterophylla	Newcastle	Saarbruck, Valenciennes.
	Grangeri		Zanesville. (Ohio.)
	flexuosa	Bath, Yorkshire, &c.	Saarbruck.
	gigantea	Newcastle	Anzin, Saarbruck, Eschweiler, &c.
	oblongata	Paulton, Somerset.	
	cordata	Leebotwood, near Shrewsbury	Alais, St. Etienne.
	Soretii	Newcastle.	
	Pecopteris longifolia.		
	blechnoides		Werden, near Dusseldorf, St. Priest. (Loire.)
	Candolliana		Alais. (Gard.)
	cyathea		St. Etienne.
	arborescens		St. Etienne, Aubin, (Aveyron,) Anzin, Mannebach.
	platyrachis		St. Etienne.
	Dithiersii		Charleroi.
	polymorpha		St. Etienne, Alais, Litry, (Calvados,) Wilkesbarre.
	oreopteroides		Le Lardin, Mannebach, Wettin.
	Bucklandii	Bath.	
	aquilina		Mannebach and Wettin.
	Schlotthemii		Mannebach, Geislautern.
	pteroides		Mannebach, Aubin.
	Davreuxii		Liege, Valenciennes.
	Mantelli	Newcastle	Liege.
	lonchitica	Ditto	Saarbruck, Silesia, Namur.
	Serlii	Bath	St. Etienne, Wilkesbarre, Geislautern.
	Grandini		Geislautern.
	crenulata		Ditto.
	marginata		Alais.
	gigantea		Abascherhütte, (Treves,) Saarbruck, Wilkesbarre, Liege.
	punctulata		Montagne des Rousses, (Oisans,) Wilkesbarre.
	nervosa		Waldenburg, Rolduc, Liege, Wales.
	obliqua		Valenciennes.
	Brardi		Lardin.
	Defrancii		Saarbruck.
	ovata		St. Etienne.
	Plukenetii		Alais, St. Etienne.
	arguta		St. Etienne, Saarbruck, Rhode Island.
	alata		New South Wales.
	cristata		Saarbruck.
	* aspera		Montrelais.
	Miltoni	Yorkshire	Saarbruck.
	abbreviata		Valenciennes.
	microphylla		Saarbruck.
	æqualis		Fresnes and Vieux Condé, near Valenciennes, Silesia.
	acuta		Saarbruck, Ronchamp. (Haute Saone.)
	unita		Geislautern, St. Etienne.
	debilis		Mines de Ronchamp.
	dentata		Valenciennes, Doutweiler.
	angustissima		Swina, (Bohemia,) Saarbruck.
	gracilis		Geislautern, Valenciennes.
	pennæformis		Fresnes and Vieux Condé, Saarbruck.
	triangularis		Fresnes and Vieux Condé.
	pectinata		Geislautern.
	plumosa	Ditto	Saarbruck, Valenciennes.
	adiantoides, Lind.	Newcastle.	
	heterophylla, Lind.	Ditto.	
	Lonchopteris Dournaisii		Valenciennes.
	cancellata.		
	Odontopteris Brardi		Le Lardin and Terrasson, (Dordogne,) St. Etienne.
	crenulata		Terrasson.
	minor		St. Etienne, Le Lardin.
	obtusa	Near Shrewsbury	Terrasson.
	Schlotthemii		Mannebach, Wettin.
	Caulopteris primæva, Lind.	Somersetshire.	
	Schizopteris anomala		Saarbruck.
Lycopodiaceæ	Lycopodites piniformis		Saxe Gotha, St. Etienne.
	polyphyllus.		
	Gravenhorstii		Silesia.
	Sillimanni.		Hadley on the Connecticut.
	Hœninghausii		Eisleben.
	imbricatus		St. George Chatellaison.
	phlegmarioides	Newcastle	Silesia.
	tenuifolius		St. George Chatellaison.
	filiciformis?		Wettin.
	affinis?		Ditto.
	Selaginites patens	Edinburgh.	
	erectus		Mont Jean, near Angers.
	Lepidodendron selaginoideum	Newcastle	Bohemia, Silesia.
	elegans		Swina, Bohemia.
	Bucklandi	Colebrook Dale.	

Family.	Name.	British Localities.	Foreign Localities.
Lycopodiaceæ	Lepidodendron ophiurus	Newcastle	Charleroi.
	rugosum		Ditto, Valenciennes.
	Underwoodii	Anglesea.	
	taxifolium		Ilmenau.
	insigne		St. Ingbert in Bavaria.
	Sternbergii	Newcastle	Swina in Bohemia.
	longifolium		Ditto.
	mamillare		Wilkesbarre.
	ornatissimum	Edinburgh, Yorkshire	Silesia.
	tetragonum	Newcastle.	
	venosum		Waldenburg, (Silesia.)
	transversum	Glasgow.	
	Volkmannianum		Silesia.
	Rhodianum	Yorkshire	Ditto, Valenciennes.
	cordatum	Durham	
	obovatum		Radnitz, (Bohemia,) Silesia, Fresnes, and Vieux Condé.
	dubium	Newcastle.	
	læve		Comté de la Marche.
	pulchellum		Alais, Liege.
	cælatum	Yorkshire.	
	varians		Wilkesbarre, Saarbruck.
	carinatum		St. George Chatellaison, Montrelais.
	crenatum		Bohemia, Eschweiler, Essen, Zanesville. (Ohio.)
	aculeatum		Essen, Wilkesbarre, Bohemia, Silesia.
	Cistii		Wilkesbarre.
	distans		St. Etienne.
	laricinum		Bohemia, Silesia.
	rimosum		Bohemia.
	undulatum		Ditto.
	confluens		Silesia, Eschweiler.
	Harcourtii, With. / imbricatum	Northumberland. (C. V. Harcourt.)	Eschweiler, Wettin.
	acerosum, Lind.	Newcastle.	
	dilatatum, Lind.	Ditto.	
	gracile	Ditto.	
	Lepidophyllum majus		Geislautern.
	lanceolatum		Montrelais.
	Boblayi		Valenciennes.
	trinerve		Montrelais.
	lineare		Alais.
	intermedium, Lind.	Near Shrewsbury.	
	Lepidostrobus ornatus	Shropshire.	
	undulatus	England.	
	emarginatus	Yorkshire.	
	major	Newcastle.	
	variabilis, Lind.	Ditto.	
	Ulodendron majus, Lind.	Barnsley, near Newcastle.	
	minus, Lind.	Halifax, Craighith, Shields.	
	Cardiocarpon majus		St. Etienne, Langeac. (H. Loire.)
	Pomieri		Langeac.
	cordiforme		Ditto.
	ovatum		Ditto.
	acutum	Newcastle	Ditto.
	Stigmaria reticulata	England.	
	Weltheimiana	Magdeburg.	
	regularis	Germany.	
	intermedia		St. George Chatellaison, Montrelais, Wilkesbarre.
	*ficoides	Leeds, Durham, Northumberland, Derbyshire, &c.	St. George Chatellaison, Montrelais, St. Etienne, Liège, Charleroi, Valenciennes, Muhlheim near Dusseldorf, Silesia, Bavaria.
	tuberculosa		Montrelais, Wilkesbarre.
	rigida		Anzin.
	minima	Anglesea	Charleroi.
Cacteaceæ?	Sigillaria punctata		Bohemia.
	appendiculata	Yorkshire	Ditto.
	peltigera		Alais.
	Cistii		Wilkesbarre.
	lævis		Liege.
	canaliculata		Saarbruck.
	rugosa		Wilkesbarre.
	Cortei		Essen.
	elongata		Charleroi, Liege.
	reniformis	Newcastle	Mons, Essen.
	hippocrepis		Mons.
	Davreuxii		Liege.
	Candollii		Alais.
	oculata	Ditto	Bohemia.
	orbicularis		St. Etienne, Saarbruck.
	* tessellata	Bath, Yorkshire, Newcastle	Alais, Eschweiler, Wilkesbarre.

Family.	Name.	British Localities.	Foreign Localities.
Cacteaceæ	Sigillaria Boblayi		Anzin.
	Knorrii		Saarbruck.
	elliptica		St. Etienne.
	transversalis		Eschweiler near Aix la Chapelle.
	pyriformis		
	Sillimanni		Wilkesbarre.
	subrotunda		Doutweiler, near Saarbruck.
	cuspidata		St. Etienne.
	scutellata.		
	pachyderma	Yorkshire.	
	notata		Saarbruck, Silesia, Liege.
	Dournaisii		Charleroi, Valenciennes.
	trigona		Radnitz in Bohemia.
	mamillaris		Charleroi.
	alveolaris		Saarbruck.
	hexagona		Borckum, near Essen, Eschweiler.
	elegans		Borckum.
	ornata.		
	Menardi.		
	Brardi		Terrasson.
	lævigata		Montrelais.
	obliqua		Wilkesbarre.
	dubia		Ditto.
	Defrancii		
	Serlii	Paulton.	
	organum, Sternb.	Newcastle.	
	monostachya	Cramlington, Northumberland.	
Coniferæ?	Sphenophyllum Schlottheimii		Waldenburg, Silesia.
	emarginatum	Bath	Wilkesbarre.
	truncatum	Somerset.	
	dentatum	Newcastle	Anzin, Geislautern.
	fimbriatum.		
	quadrifidum		Terrasson.
	dissectum		Montrelais, St. George Chatellaisen.
	erosum, Lind.	Ditto.	
	Pinites Brandlingi, Lind.	Ditto.	
	Withami, Lind.	Edinburgh.	
	medullaris, Lind.	Ditto.	
	ambiguus, With.	High Heworth.	
	Pitus antiqua, With.	Lennel Braes, near Coldstream.	
	Anabathra pulcherrima, With.	Tweed Mill.	
	Peuce Withami, Lind.	Durham.	
Palmæ	Flabellaria? borassifolia		Swina in Bohemia.
	Nœggerathia foliosa		Bohemia.
	flabellata	Newcastle.	
	Zeugophyllites calamoides		Raña Gunje, near Rajemahl, India.
Cannæ	Cannophyllites Virletii	Yorkshire.	
	Sternbergia angulosa	Ditto.	
	approximata		Langeac, St. Etienne.
	distans	Edinburgh.	
	Poacites lanceolata		Zanesville. (Ohio.)
	æqualis		Terrasson.
	striata		Ditto.
Glumaceæ	Cyperites bicarinata, Lind.	Near Shrewsbury.	
	Trigonocarpon Parkinsonis	England, Scotland.	
	Nœggerathi		Langeac, Coal Mines on the Rhine.
	ovatum		Ditto.
	cylindricum		Ditto.
	dubium		Ditto.
	Musocarpum prismaticum		Ditto.
	difforme		Ditto.
	contractum	Oldham.	
(Class doubtful)	Phyllotheca australis		Hawkesbury River, New Holland.
	Annularia minuta		Terrasson.
	brevifolia		Alais, Geislautern.
	fertilis	Bath	St. Etienne, Wilkesbarre.
	floribunda		Saarbruck.
	longifolia	Camerton	Geislautern, Silesia, Alais, Wilkesbarre.
	——— B.		Charleroi, Terrasson.
	spinulosa		Saxony.
	radiata		Saarbruck.
	Asterophyllites equisetiformis		Mannebach, (Saxony,) Rhode Island.
	rigida		Alais, Valenciennes, Charleroi, Bohemia
	hippuroides		Alais.
	longifolia	Newcastle	Eschweiler.
	tenuifolia	Ditto.	Silesia.
	tuberculata	Ditto.	Germany.
	delicatula		Charleroi, Anzin.

Family.	Name.	British Localities.	Foreign Localities.
(Class doubtful.)	Asterophyllites Brardi		Terrasson.
	dubia	Newcastle.	
	diffusa		Radnitz, Bohemia.
	grandis, Lind.	Ditto.	
	foliosa, Lind.	Ditto.	
	galioides, Lind.	Barnsley.	
	Volkmannia polystacha		Waldenburg. (Silesia.)
	distachya		Swina. (Bohemia.)
	erosa		Terrasson.
	Polyporites Bowmanni, Lind.	Near Wrexham.	

Nearly all the names of fossil plants are taken from Brongniart; the few from Lindley and Hutton, from Sternberg and Witham, are marked by suitable abbreviations.

Analogy to existing plants.

The following observations by M. Adolphe Brongniart contain nearly all that can be at present advanced concerning the physical conditions which governed the growth of these plants. We shall first remark that since the date of M. Brongniart's Essay, true coniferæ have been discovered in the English coal districts, and that his reference of sigillaria to the tribe of arborescent ferns appears open to very serious objections, and is perhaps not generally allowed. Besides the few coniferæ and monocotyledones, "the flora of this epoch is composed almost wholly of vascular cryptogamous plants, so that out of 260 species 220 belong to this class. But, though evidently ranging themselves in the families of equisetaceæ, filices, and lycopodiaceæ, these plants differ from the species, and often from the genera now in existence, in several points of their organization, and especially by their gigantic size. At this period there existed equiseta more than ten feet in height, and five or six inches in diameter, tree ferns forty or fifty feet, and arborescent lycopodiaceæ sixty or seventy feet high. The essential characters of this 'primary' vegetation are the *numerical predominance* and *great magnitude* of these cryptogamic plants.

"It has been long observed, that the plants of this age resembled generally those of the hot, rather than of the temperate regions of the Globe; but since the fossil plants have become much better known, and their analogy with existing tribes founded upon a more thorough examination, their relation to the plants of Equatorial regions may be established on a more solid basis. All cryptogamic plants acquire greater size, in proportion as the climate is hotter; or rather, in cold climates none but very small species of this class are found, while in tropical regions we have, in addition, many of large size. The ferns of cold and temperate climates are upon the soil, or their stem rises only a few inches in height; those of tropical regions grow to ten or twenty feet: the smallest equiseta known are those of Lapland and Canada; the largest grow in the West Indies, and Equinoxial America; the lycopodia of our climates are never above five or six inches high, those of tropical regions are three or four times as high.

"The *numerical predominance* of the cryptogamic tribes in the carboniferous epoch is such that, while in the existing order of Nature they are to the whole number of plants known as 1 to 30, they were in that ancient epoch in the proportion of 27 to 30."

If we seek to determine by comparison with *particular or local existing floras*, the probable circumstances under which cryptogamic plants grew to such preponderance in the carboniferous epoch, we shall be guided by the observations of Brown and D'Urville to some important results. According to these eminent Botanists, the family of ferns is subject to the influence of two causes, which determine their mode of distribution over the Globe; heat of climate, and the influence of the humid air and uniform temperature of the sea. Hence, when the circumstances depending on proximity to the sea are equal, these plants are more abundant in the Equatorial than in colder regions, but in the same zone of climate they are much more abundant in isles than on continents. In the temperate parts of the Continent of Europe, under favourable circumstances, they are to the phanerogamic tribes as 1 to 40; within the tropics Brown states the ratio as 1 to 20, and in unfavourable situations as 1 to 26. Under the same latitude, this proportion becomes much greater in Islands; in the West Indies the ferns are as 1 to 10, instead of 1 to 20, as in favourable situations on the Continent of equinoxial America; in the South Sea Islands 1 to 4, or 1 to 3; while on the Continent of India and in the tropical part of New Holland the ratio is 1 to 26. At St. Helena and Tristan d'Acuyna the cryptogamia are to the phanerogamia as 2 to 3, and in Ascension nearly as 1 to 1.

From these examples it is plain, that the smaller the isles, and the more remote they are from great continents, the larger is the proportion of ferns growing there; and we may conceive that if such islands were alone in the midst of a vast ocean, or formed only scattered points or little clusters without any great continent, their proportion of ferns would be still greater, and the cryptogamia become the predominant group. Geologists have, from independent considerations, inferred that at the time of the formation of coal, the extent of land in the position of our present continents was very small compared to the wide surface of the sea; and thus Geology and Botany appear to agree in determining that at this period, and in the situations where afterwards coal was formed, land existed only in small islands, amidst extensive seas. On these islands, under perhaps a more than tropical climate, in an atmosphere charged with moisture, we may believe that those gigantic cryptogamia grew which have produced so large a proportion of the extended coal beds of the older carboniferous epoch.

POLYPARIA.

Family.	Name.	British Localities.	Foreign Localities.
Cellulifera	Flustra crinoidea, Miller.	Arran.	
	Retepora flustraformis, Mart.	Middleton, Derbyshire, Arran.	
	elongata, F.	Rutherglen, Lanark.	
	Cellepora Urii, F.	Rutherglen.	
	Aulopora compressa, G.		Ratingen.
	Catenipora	Winster.	

Family.	Name.	British Localities.	Foreign Localities.
Cellulifera	Tubipora ramulosa	Mendip, Westmoreland, Ireland.	Olne, Limburg.
	Syringopora reticulata		Olne.
	radiata, Mart.	Winster.	
	strues, L.	Westmoreland.	
	tubularia L.		Liege.
	Favosites septosus, F.	Scotland.	
	depressus, F.	Ditto.	
	ramosus	Arran.	
	*Calamopora polymorpha, G.		Namur, Elberfeld.
	Millepora, undescribed, Sp.	Near Kirby Lonsdale, in thin beds.	
	undescribed, Sp.	Near Middleham, near Kirby Lonsdale.	
Lamellifera	Cyathophyllum excentricum, G.		Ratingen.
	pentagonum, G.		Namur.
	Lithostrotron striatum, Park	Wales.	
	floriforme, Mart.	Bristol.	
	marginatum, F.	Scotland.	
	Caryophyllia fasciculata	Bristol	At Namur two species of Caryophyllia.
	duplicata, Mart.	Bakewell	
	affinis, Mart.	Winster	
	juncea, F.	Rutherglen	
	Turbinolia fungites, F.	Yorkshire, Rutherglen, Ireland	Liege, Namur.
	Astrea undulata, Park	Bristol.	
	Porites cellulosa, Park	Mendip.	
	*Amplexus coralloides, Sow.	Anglesea, Limerick.	

These thirty or more species of polyparia appear almost wholly distinct from those of the slate system, yet they belong mostly to the same genera. They have as yet been little noticed in the carboniferous limestone of Belgium and Westphalia. No polyparia have yet been seen in the proper coal measures; they all belong to the subjacent limestone group.

Radiaria.

Family.	Name.	British Localities.	Foreign Localities.
Crinoidea	Pentremites ellipticus, Sow.	Preston.	
	Derbiensis, Sow.	Derbyshire, Ireland.	
	globosus	Bath.	
	undescribed species	Craven in Yorkshire.	
	ovalis, G.		Ratingen, Dusseldorf.
	Poteriocrinus crassus	Yorkshire, &c. Bristol, Arran.	
	tenuis	Mendip, Bristol.	
	Platycrinus lævis	Bristol, &c.	
	rugosus	Mendip, Caldy Island, Whitwell.	
	tuberculatus	Mendip, Whitwell, Yorkshire.	
	granulatus	Ditto, ditto, ditto.	
	striatus	Bristol.	
	*pentangularis	Ditto, Mendip.	
	depressus, G.		Ditto.
	Cyathocrinus planus	Northumberland.	
	quinquangularis	Bristol.	
	*rugosus	Whitwell, Yorkshire.	
	Actinocrinus *30 dactylus	Ditto, ditto, Ireland.	
	polydactylus	Whitwell, Mendip.	
	lævis		Ditto.
	Gilbertsoni	Whitwell, Yorkshire.	
	granulatus, G.		Ditto.
	Rhodocrinus *verus	Whitwell, Bristol, Dean Forest.	
	quinquangularis	Whitwell.	
	Eugeniocrinus, undescribed	County Fermanagh, Ireland.	
Echinida	Cidaris, with large mammellæ and muricated spines. Phil. MS.	Yorkshire, Northumberland, Westmoreland.	

No radiaria have yet been seen in the proper coal measures, they all belong to the subjacent limestone group, which in some extensive tracts is almost wholly composed of their disjointed columns and other parts. The names are principally from Miller's Work on the crinoidea; where other authors are quoted, their names are appended to the particular species described by them.

Conchifera.

Family.	Name.	British Localities.	Foreign Localities.
Plagymyona	Pholadomya ? undescribed, Sp.	Castleton.	
	Corbula limosa, F.	Scotland.	
	Sanguinolaria gibbosa	Queen's County, Ireland.	
	Tellina lineata, H.		Ratingen.
	Cardium *alæforme	Isle of Man, Arran, Queen's County.	
	Hibernicum	Cork, Mendip.	
	elongatum	Bakewell, Whitwell, &c.	
	Hiatella sulcata, F.	Frith coal field, North Britain.	
	Isocardia oblonga	Dublin.	

Family.	Name.		British Localities.	Foreign Localities.
Plagymyona	Cypricardia annulata			Visé, near Liege.
	Nucula palmæ		Derbyshire.	
	attenuata, F.	Shale	Rutherglen.	
	gibbosa, F.	Ditto	Ditto.	
	———		Northumberland.	
	Anodon? crassus		Wigan. Leeds?	
	Unio Urii, F.	Coal	Rutherglen.	
	subconstrictus		Yorkshire, Newcastle, &c.	Liege.
	acutus		Ditto, ditto	Ditto, Werden, Bochum.
	other species		Yorkshire, Derbyshire.	
	Chama? antiqua, H.			Ratingen.
	Modiola lævis		Barry Isle	
	undescribed species		Castleton.	
	Goldfussii, H.			Ditto, Visé.
	Megalodon *cucullatus		Yorkshire.	
Mesomyona	Mytilus crassus, F.	Shale	Cult hills, Fife, Wigan	Werden,
	minimus, H.			Near Cologne.
	Pinna flabelliformis, Mart.		Ashford	Ratingen.
	Inoceramus vetustus		Castleton	Ditto.
	Pecten, undescribed, Sp.		Ditto, Yorkshire, Ireland.	
	priscus, Schl.			Ditto.
	plicatus		Queen's County.	
	granosus		Ditto.	
	dissimilis, F.		Scotland.	
	papyraceus	Coal	Leeds, Sheffield, Halifax	Liege, Werden.
	undescribed species		Northumberland.	
	Avicula, undescribed species		Ditto.	
	Vulsella? cingulata, H.		Bradford, Sheffield	Visé, near Liege.
	Posidonia, B.		Flasby in Craven, Yorkshire, Ireland.	
	undescribed		Bradford, Yorkshire.	
	Ostrea prisca, H.			Visé.
	Hinnites Blainvillii, H.			Ratingen.
Brachiopoda	Orbicula reflexa?	Ironst.	Coalbrook Dale?	
	undescribed species		Northumberland.	
	Terebratula acuminata		Buxton, Scalebar, Clithero, &c.	Ditto.
	*crumena		Winster.	
	*pugnus		Croom, Ireland, &c., Clithero.	
	*? platyloba?		Clithero.	
	* lateralis		Black Rock, Cork, Dublin	Ditto.
	*Mantiæ		Ireland.	
	*cordiformis		Ditto.	
	*reniformis		Dublin	Ditto.
	hastata		Bristol, K. L. &c.	
	*sacculus		Middleton, Matlock, K. L.	
	dubia, D.		Ireland.	
	Durassii, D.		Dublin.	
	? indentata			Ditto, Visé.
	obliqua			Ratingen.
	monticulata, Schl.			Visé.
	*lævigata, Schl.			Ditto.
	Spirifera resupinata (Tereb. Sow.)		Dovedale, Clithero, Rutherglen	Ratingen.
	Martini		Castleton, Bristol.	
	* cuspidata		Ditto	Ditto.
	trigonalis		Cavedale and Overton	Visé, Ratingen.
	triangularis		Buxton, Derbyshire.	
	*undulata		Arran. (East Thukley.*)	
	*octoplicata		Ditto	Ditto.
	*glabra		Chelmerton and Ireland	Ratingen.
	*striata		Bakewell, Arran	Namur, Ratingen, Liege.
	*ambigua		Ditto	Ratingen.
	minima		Ditto.	
	*obtusa		Scalebar, Yorkshire	Ditto, Liege.
	*lineata		Castleton.	
	imbricata		Ditto, Little	Ditto, ditto.
	oblata		Flintshire, Derbyshire	Visé, Liege.
	*pinguis		Black Rock, Ireland.	
	*attenuata		Ditto.	
	bisulcata		Ditto	Visé.
	*distans		Ditto.	
	*rotundata		Torquay, Limerick	Ditto.
	Urii, F.		Rutherglen.	
	exarata, F.		West Lothian.	
	biplicata, G.			Ratingen.
	Lingula mytiloides		Wolsingham.	
	———		Rutherglen.	
	Producta *longispina		Kilbride, Lanarkshire.	
	spinulosa		Linlithgow	Ditto, Visé.
	Flemingii		Livingstone, ditto.	
	spinosa		Ditto, Arran	Ratingen.
	Scotica		Linlithgow, Arran, Isle of Man	Liege, Visé.

Family.	Name.	British Localities.	Foreign Localities.
Brachiopoda	Producta aculeata	Bakewell.	
	gigantea	Ditto, Yorkshire.	
	*scabricula	Milldale, Derby, Arran, Northumberland	Visé.
	*Martini	Derbyshire, Ashford, Arran, Yorkshire.	Ratingen, Visé.
	crassa	Buxton, Derby.	
	striata	Croom, Ditto.	
	semireticularis	Derbyshire.	
	antiquata	Ditto, Dublin.	Ditto, ditto.
	*sulcata	Ditto	Visé, Liege.
	personata	Ditto, Kendal	Ratingen.
	punctata	Buxton, Yorkshire, Ireland	Visé. Ratingen.
	fimbriata	Derbyshire, Yorkshire	Ratingen. Visé.
	plicatilis	Ditto	Ratingen, Liege.
	*horrida	Arran.	
	hemisphærica	Mynydd Carreg, Yorkshire	Ratingen, Visé, Liege.
	comoides	Llangavenni, Anglesea	Ratingen.
	latissima	Puffin Island, Arran	Ditto, Visé, Liege.
	cancrina	Richmond, Derbyshire	Ditto, ditto.
	lobata	Clifton, Cumberland, Northumberland, Arran	Ditto, ditto, ditto.
	costata	Gloucestershire, Glasgow.	
	humerosa	Bredon, Derbyshire.	Ratingen.
	Crania prisca, H.		Ditto.

The names in the preceding catalogue of conchifera are almost wholly taken from Sowerby's *Mineral Conchology*; where other authors are quoted, their names are appended to the particular species described by them.

The conchifera of the carboniferous system admitted in the preceding lists amount to 112.

Plagymyona 25, mesomyona 17, brachiopoda 70. Of these 3 plagymyonous, 7 mesomyonous, and 31 brachiopodous, are said to be also found in the slate system. On this subject the remarks which follow the enumeration of the conchifera of the slate system may be referred to. Mesomyonous bivalves have now become more numerous, and the enormous preponderance of brachiopoda over the other orders of bivalves is reduced from 6 to 1 to about 2 to 1.

Of these 112 species, 5 are generally allowed to be fluviatile or lacustrine; and their number, if augmented by the yet undescribed species in England, may very probably amount to 10. Nearly all the marine tribes occur in the limestone group below the coal measures; all the fresh-water species lie in the coal measures; but there is one thin layer of marine shells extensively spread in Yorkshire, in the midst of the coal measures, *above certain fresh-water layers* and *below several others*. No fresh-water shell lies in this bed. Hence the series of operations by which that coal field has been formed evidently includes one period of marine, and two of fluviatile or lacustrine action, subsequent to the general and long-continued action of the sea, which deposited the mountain or carboniferous limestone. There is no disturbance of strata nor any thing to indicate local movement during the deposition of the coal, and it is presumed that the alternation of marine and fresh-water deposits, here certainly proved, was occasioned by causes acting at a distance. An additional memoir has been promised on this subject. (See p. 590.)

Mollusca.

	Name.	British Localities.	Foreign Localities.
Gasteropoda Holostomata	Pileopsis* vetusta	Near Clithero.	
	tubifer	Ditto.	
	some other species	Ditto.	
	Patella, several species	Ditto.	
	primigena, Schl.		Ratingen.
	Planorbis, Phil.	In coal measures, Yorkshire.	
	Planorbis equalis	Kendal.	
	Ampullaria nobilis	Queen's County, Ireland.	
	helicoides	Ditto.	
	undescribed	Clithero, Westmoreland.	
	Melania *constricta	Buxton, Tideswell.	
	Nerita striata	Corry, Arran.	
	*spirata	Bristol, Derbyshire.	
	other species	Clithero, Northumberland.	
	Natica elongata, Hsen.		Ditto.
	Gaillardotii		Ditto.
	globosa		Visé.
	patula		Ratingen.
	undescribed species	Clithero, Northumberland.	
	Pleurotomaria (Helix, Sow.) carinata	Derbyshire, Yorkshire	Visé.
	striata	Derbyshire	Ditto.
	several undescribed species	Near Clithero.	
	Cirrus* acutus	Ditto, Derbyshire	Namur.
	rotundatus	Ditto.	
	several undescribed species	Ditto.	
	Euomphalus nodosus	Derbyshire	Ratingen.

Family.	Name.	British Localities.	Foreign Localities.
Gasteropoda Holostomata	Euomphalus angulosus.		
	*catillus	Derbyshire, Yorksire	Ratingen.
	delphinularis, Hæn.		Ditto.
	pentangulatus	Ditto, ditto	Ditto, Namur.
	tuberculatus, F.	West Lothian.	
	coronatus		Vise, Ratingen.
	rotundatus		Ditto ditto.
	other undescribed species	Near Clithero	Visé.
	Turbo *tiara	Ditto.	
	helicinæformis		Ratingen.
	undescribed species	Northumberland.	
	Trochus cingulatus, G.	Several undescribed species at Clithero.	Ditto.
	scalaris, G.		Ditto.
	alutaceus		Visé.
	catenulatus, G.		Ditto.
	tæniatus		Ratingen
	Turritella angulata		Ditto.
	Urii, F.	Rutherglen.	
	elongata, F.	Ditto.	
	spinata, G.	Several undescribed species.	Ditto.
	angustata, G.		Ditto.
	conoidea, G.		Ditto.
	tenuis, G.		Ditto.
	acuminata, G.		Ditto.
	Phasianella auricularis		Ditto.
	striata		Ditto.
Gasteropoda Solenostomata	Buccinum acutum	Queen's County, Ireland.	
	undescribed species	Near Clithero.	
	Rostellaria ?	Ditto.	

This catalogue of gasteropodous mollusca is very incomplete. At least as many more species, most of which are in the possession of Mr. W. Gilbertson of Clithero, remain to be added to it from the mountain limestone of Yorkshire alone. Several others were collected by the late Mr. Miller near Bristol, and by the Rev. C. V. Harcourt in Northumberland.

Mollusca.

mily.	Name.	British Localities.	Foreign Localities.
Cephalopoda Monothalamia	Bellerophon *hiulcus	Derbyshire, Yorkshire	Visé, Ratingen.
	*costatus	Derbyshire, Dublin	Ditto, ditto.
	*tenuifascia	Settle, Kendal, Ireland	Ratingen, Visé.
	*apertus	Settle, Ireland.	
	*cornu arietis	Kendal.	
	Urii, F.	Rutherglen.	
	decussatus, F.	Linlithgow.	
	striatus, F.	Ditto.	
	depressus, Montf.		Ratingen.
	vasulites, Montf.		Namur.
	undescribed	Yorkshire, Westmoreland.	
	imbricatus, G.		Ratingen, Visé.
	sulcatus, G.		Ratingen.
Cephalopoda Polythalmia	Orthocera giganteum	Closeburn.	
	cordiforme	Ditto	Visé.
	undulatum	Clithero, Settle.	
	Breynii	Ashford, Clithero.	
	fusiforme	Clithero, Queen's County.	
	cinctum	Clithero.	
	Gesneri. Mart.	Ashford.	
	læve, F.	Linlithgow.	
	pyramidale. F.	Ditto.	
	cylindraceum. F.	Livingstone.	
	annulare. F.	Linlithgow.	
	rugosum, F.	Ditto	
	angulare. F.	Ditto.	
	attenuatum. F.	Livingstone.	
	sulcatum, F.	Ditto.	
	undatum, F.	Ditto.	
	Steinhaueri	Halifax, Yorkshire.	
	Conularia sulcata	Bristol, Rutherglen, Coalbrook Dale	
	teres	Scotland.	
	Nautilus complanatus	Isle of Man.	
	Henslowi	Ditto.	
	*globatus	Yorkshire	Ratingen.
	multicarinatus	Ditto.	
	bilobatus	Closeburn, Yorkshire.	
	pentagonus	Closeburn, Kendal.	
	tuberculatus	Closeburn.	
	discus	Kendal.	

Family.	Name.	British Localities.	Foreign Localities.
Cephalopoda Polythalmia	Nautilus Woodwardii	Winster, Yorkshire.	
	sulcatus	Castleton.	
	ingens	Ashford.	
	biangulatus	Bristol, Yorkshire.	
	*cariniferus	Yorkshire.	
	excavatus, F.	Limerick.	
	marginatus, F.	Bathgate.	
	quadratus, F.	West Lothian.	
	Luidii	Ashford, Ireland.	
	undescribed	Sheffield.	
	Ammonites striatus	Buxton, Castleton, Craven.	
	sphæricus	Milldale, Craven	Liege, Werden.
	Listeri	Middleton, &c. Sheffield	Liege.
	undescribed	Ecton.	
	several new species	Yorkshire and Lancashire.	
	carbonarius, G.		Ditto, Werden, Wettin.
	Henslowi	Isle of Man, Yorkshire.	

The mollusca of the carboniferous epoch are but imperfectly known, notwithstanding the labours of Sowerby, Fleming, and others, and we can hardly venture to expect that the numerical relations of even the leading divisions will remain unchanged, when the numerous additional species shall have been described. The present ratios are, gasteropoda about 55, cephalopoda 57, of which 16 are monothalamic, which are not very different from the proportions in the slate system. Above this epoch, monothalamic cephalopoda disappear wholly until new tribes of them are recognised above the chalk. It is proper to mention that the situation which we assign to bellerophon among the cephalopoda is not admitted by all Naturalists. The names of the mollusca are from Sowerby, except where other authors are quoted.

Family.	Name.	British Localities.	Foreign Localities.
Crustacea	Asaphus Dalmanni, G.		Ratingen.
	Calymene Derbiensis, Mart.	Ashford.	
	lunatus, D. Ironst.	Mansfield, Notts.	
	Cancer a claw	Northumberland.	
Annulosa	Serpula compressa	Lothian.	
Fishes	Ichthyodorulites	(Mr. Ludlow,) Bristol, &c.	
	Palates	Bristol, Westmoreland, Northumberland.	
	Scales	Caithness.	
	Dipterus brachypygopterus	Ditto.	
	macropygopterus	Ditto.	
	Valenciensii	Ditto.	
	macrolepidotus	Ditto.	
	Osteolepis macrolepidotus	Ditto.	
	microlepidotus	Ditto.	
	Saurian vertebra	"In gravel of limestone." Northumberland. (C. V. Harcourt.)	

General Summary.

569 species of organic remains, of which 62 are stated to be found in the slate system below, and 8 in the magnesian limestone above.

Plants	274 species	Terrestrial, of which (omitting sigillaria) about 190 are cryptogamous and 40 phanerogamous.
Polyparia .	30 ..	Cellulifera 17, lamellifera 13.
Radiaria ..	26 ..	Amongst these echinida distinctly appear.
Conchifera	112 ..	Plagymyona 25, mesomyona 17, brachiopoda 70.
Mollusca ..	112 ..	Gasteropoda 55, cephalopoda 57.
Annulosa ..	1 ..	
Crustacea .	4 ..	
Fishes	10 ? ..	
Saurian ..	— ..	
	569	

Saliferous System.

It has been shown that the consolidated deposit of coal was subject to the effects of a very general eruption of igneous agency from beneath, and that in this manner the whole arrangement of those deposits was altered, and many parts of the bed of the sea uplifted to form dry land. In the large but very irregular area left between these islands of carboniferous strata, the sea began to deposit limestones commonly charged with magnesia, sandstones remarkably coloured with red oxide of iron, and clays and marls of red, blue, and white colours; the whole series being, in general, far from rich in organic remains, seldom traversed by metallic veins, and not so much dislocated by faults as the older strata. Salt, in beds or nodules, accompanied by gypsum, lies very commonly in this series of rocks, and hence it may be termed emphatically the saliferous system. Generally, its stratification is wholly unconformed to that of the subjacent coal measures, on whose elevated edges, breaks, and dykes, its planes rest level and undisturbed.

In the composition of this group we find traces of all the various operations of the sea; limestones crystallized, compact, brecciated, conglomerated, and earthy, full of magnesia, or containing carbonate of lime with little or no admixture. Locally rich in organic remains, but generally devoid of them; sandstones coloured red, blue, or white, in stripes and spots, fine grained, coarse grained, or full of innumerable pebbles, derived from primary and secondary rocks; clays and marls of many various hues; both the sandstones and clays locally productive of the remains of saurians, shells, and plants, but over large tracts wholly destitute of them. These

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organic remains are partly analogous to those of the carboniferous system, and partly to those which occur in the more recent oolites, and the whole formation, though so peculiar in character as to be readily, and indeed unavoidably, separated from both those systems, offers by many resemblances, besides its intermediate position, a natural transition from the one to the other.

This may perhaps appear to those who only have seen the saliferous system in England, where its total unconformity to the coal, and dissimilitude to the strata above and below, are matter of notoriety, a proposition deserving further explanation. The facts on which it rests will be found in the following pages, and they will give reason to presume that when we have assembled data sufficient for satisfactory induction, those *interruptions in the series* which appear to indicate great and sudden revolutions will be proved to be merely local, and to arise from the *omission* in certain situations of strata elsewhere deposited in great force.

It has already been stated that in the Island of Arran the primary strata are succeeded by a very thick series of red and white sandstones and conglomerates, and that coal measures and carboniferous limestone lie included in this mass like subordinate or local formations. The conglomerates below the limestone represent the old red sandstone, and the upper sandstones above the coal represent the new red sandstone formation, and it might be possible to include the whole of the carboniferous and saliferous systems of rocks together under the name of red sandstone formation. This is the view of the subject taken by Von Hoffman, from observations in the North-Western part of Germany, where in a mass three or four thousand feet thick of red and white sandstones, lie the diminished strata of coal.

Nevertheless, these cases, though affording very instructive inferences as to the continuity of the operations of Nature, are not to be taken as general types of the series of strata, and throughout the greater part of the British Islands, as well as in the South-East of France and in Germany, the saliferous red sandstone series, with its accompanying limestones and marls, is a distinct system of strata, characterised by peculiar features of mineral composition, and organic contents, and marked by a general aspect of physical geography.

England.

In England, supposing all the parts of the saliferous system of rocks present in one section, we should have, reposing unconformably on the coal strata, the following classification, beginning from above.

4. Series of coloured marls	Purple coloured marls below the lias.
	Alternations of red and bluish white marls, with layers and nodules of gypsum.
	Thin layers of argillo-calcareous stone.
	Red and bluish marls with gypsum and beds of rock salt.
3. Variegated red and white sandstone (Pœcilite of Conybeare)	Red and white sandstone, mostly fine grained, and often impregnated with salt.
	Red conglomerate, full of pebbles of older rocks.
2. Magnesian limestone.	Red and white marls.
	Thin bedded compact limestone, with very little magnesia and few organic remains.
	Red and white marls and gypsum.
	White, yellow, or reddish magnesian limestone in thick beds, crystallized, compact, or earthy, often full of sparry cavities, and containing marine organic remains.
	Marl slate, in thin layers, occasionally enclosing fishes.
1. Yellow or purple sand and sandstone and marl	An extremely variable series of sandstones, sands, and clays, of various colours, irregular thickness, and much local diversity of character.

Range of the Saliferous System in England.

Of the beds included in this arrangement, the calcareous strata are perhaps the least extensive, yet, as usually happens, they are most regular and continuous in their ranges, and most consistent in characters, and afford the best data for the classification of the others. By looking at Mr. Smith's, or Mr. Greenough's Geological Map of England, the extent of the range of magnesian limestone may be observed from the North side of the Tyne uninterruptedly to the Tees, between which river and a place called Thornton Watlas, it is known only in a few points, though probably it exists continuously beneath the superficial accumulations of gravel. From this point to Bilborough, near Nottingham, its course is uninterrupted.

Below it, in a narrow, irregularly parallel tract to the West, reposing on all the members of the coal formation indiscriminately, runs the lower series of sandstones and marls, above on the East through Yorkshire and Nottinghamshire ranges the conglomerate red sandstone, and upon this lies, through Durham, Yorkshire, and Nottinghamshire, the series of upper coloured marls and gypsum.

Cumbrian district.

On the Western side of the summit ridge of the North of England, the vale of the Eden is filled by the new red sandstone formation, consisting principally of coarse or fine-grained red sandstone, and red marl above, with, in one place, a remarkable series of conglomerate, or rather brecciated beds at the bottom, and in another a distinct deposit of magnesian limestone. The former are seen at Kirby Stephen in the angle between two lines of dislocation and afford a very instructive point of comparison with an analogous deposit in Somersetshire, known by the name of millstone. It has a basis of red sandstone almost entirely filled with angular fragments of different sizes of the neighbouring limestone strata; it is disposed in vast unequal beds, with large distant joints almost invariably ranging North and South, lies with a dip to the East between the lines of two dislocations of the carboniferous limestones, to the violence accompanying which its own production was probably owing. It is not in general magnesian, yet some yellow beds probably contain that substance, and thus we are led to refer its production to the date of the lower parts of the magnesian limestone.

No further trace of beds analogous to the magnesian series of Yorkshire and Durham occurs, in the Westward extension of the new red sandstone group round the Cumbrian mountains, till we reach Whitehaven, where magnesian limestone and conglomerate, lying in red sandstone, are sunk through in the coal pits, and seen in the high cliffs against the sea towards St. Bee's Head. From Professor Sedgwick's examination of this district we learn that the section here presented is more closely similar to that of Yorkshire than was previously supposed, and that the following groups are uniformly laid upon the coal system.

3.	Variegated red sandstone of St. Bee's Head.
2. Magnesian limestone.	Red marl and gypsum.
	Magnesian limestone sometimes replaced by or alternating with magnesian conglomerate.
	Magnesian conglomerates, analogous to those in the vale of Eden, and various parts of Yorkshire.

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1. { Coarse reddish sandstone of great thickness on the whole unconformed to the coal measures, but also in part unconformed to the rocks above, which lie in its hollows.

In their Northward extension beyond the Solway Frith to Dumfries-shire and Galway, the red sandstone strata do not exhibit any traces of magnesian limestone.

Midland Counties.

Beyond the Southern termination of that rock, near Nottingham, the variegated red sandstones and coloured marls spread themselves over the whole area between Leicester, Warwick, and Worcester, on the one side, and Shrewsbury, Chester, Liverpool, on the other, and extend Northwards to Manchester, Leek, and Ashbourn. Yet in all this immense area, except at Ardwick, near Manchester, and near Shrewsbury, we nowhere find any deposits analogous to the magnesian limestone. At Ardwick a limestone is dug containing, as we have been informed by Dr. Henry, magnesia; and we may believe that its geological situation is similar. In this neighbourhood also, as at Worsley collieries, we appear to recognise the lower red sandstone of Yorkshire, in several places overlying the coal beds, and it is probable that further examination may extend these points of agreement. Near Shrewsbury, likewise, the coal strata are preceded by what appears to correspond to the lower red sandstone, and upon this lies a porphyritic magnesian conglomerate.

South of England.

South of Worcester the variegated sandstones and marls, the latter predominating, pass down the Vale of the Severn, fill up the winding intervals of the dislocated carboniferous limestone, partly cover the coal basins of Somersetshire, spread in the vales of the Parret and the Exe, and reach the sea at Exmouth.

The only parts of this extensive range where magnesian rocks appear distinctly, is amongst the limestone and coal tracts of Somersetshire and South Gloucestershire. Along the sides of Mendip magnesian conglomerates of considerable extent separate the limestone from the red sandstone, and produce the ores of zinc; a similar deposit, in similar relation to the older limestone, appears along the Avon below Clifton, and at Radstock and other places it is pierced in the collieries, at or near the bottom of the red sandstone, and receives the name of millstone. Conglomerates of a very singular, even porphyritic, character occur near Exeter, in the lower part of the variegated sandstone and marls, and from a general review of the whole subject, Professor Sedgwick classes the conglomerates of Exeter, Somersetshire, and Shropshire, with the lower or conglomerate portion of the magnesian limestone of the North of England. Some doubt may perhaps yet remain as to the propriety of including in this system the red conglomerate of Exeter, which is by Mr. De la Beche ranked with the rothetodteliegende, but in the other points the inference appears certain.

From this view of the subject which we fully adopt, it would appear that the difference of the saliferous system, in different parts of England, arises rather from the limited continuity of the beds, than from any great variation in their quality or relations. The series of the saliferous system is perhaps nowhere more complete than in the interval between the Wharfe and the Dun, yet even here several beds are deficient. The marl slate and conglomerate limestones are better studied in Durham, the upper coloured marls are better exhibited in Nottinghamshire, and the beds of salt must be examined in Cheshire.

Remarks on certain Members of the Saliferous System in England.

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Variegated sandstones and clays.

The variegated sandstones and coloured clays of the British series, being destitute of organic remains, and subject to no very remarkable changes of character, what has been said will suffice for the purpose of comparison between them and the analogous deposits in other parts of Europe. But before we proceed to this comparison, it will be useful to describe more particularly the general characters of the terrace of magnesian limestone, and its associated strata, which occupies so remarkable a range in the North of England. The table already given will explain the relation of the several members of this group, and we shall at present confine our attention to the calcareous portions. The most ample details on every point will be found in Professor Sedgwick's Paper in the *Geological Transactions*.

Marl slates.

Immediately above the lower red sandstone in the excavation for the Stockton Rail-road, were found in ascending order, (1.) thirty feet of light-coloured, silicious sandstone in thin beds, alternating at the top with blue calcareous slate. (2.) Nine feet of yellow calcareous shale and marl slate, some of the beds incoherent and sandy. In this marl slate about two feet above the sandstone were found many impressions of vegetables (ferns) and fishes of the genus palæothrissum. The higher and more compact beds also contained productæ, spiriferæ, and terebratulæ. The shales or marls of this series are sometimes highly bituminous. (3.) Twenty feet of thin calcareous beds with marly partings.

These slaty marls and limestones have a very irregular extent even in Durham, and are imperfectly traceable in Yorkshire. They are perhaps best exhibited at Garforth Cliff, on the road from Leeds to Selby, where they are full of axinus obscurus, and contain a species of producta not yet described. Deposits somewhat analogous are described by Professor Sedgwick near Bolsover. Little or no magnesia is found in this part of the series.

Yellow magnesian limesto[ne]

The yellow magnesian limestone whose extreme thickness between the Aire and the Dun certainly exceeds 300 feet, exhibits the most astonishing diversity of mechanical structure, without a corresponding diversity of chemical composition or definite geological divisions. Several varieties yield upon analysis carbonate of magnesia and carbonate of lime, in the simple proportion of atom to atom, (for example, the building stone of Huddleston and Warmsworth,) and in almost all the proportion of magnesia is large. In the Southern part of its range, the structure of the rock is generally crystalline, and the crystals (rhomboids) being small, and often tinged of a reddish or yellow colour, the whole might be easily mistaken for sandstone. On the contrary, in the Northern part of its range, a concretionary structure is often observed, and thus globular masses of carbonate of lime of various magnitude compose beds of stone or lie loose amongst a quantity of yellow, powdery, calcareo-magnesian carbonate. But the variety of the appearances presented by this kind of structure is so great, that on entering a quarry near Sunderland we are struck by the organic aspect of the whole escarpment, as if it had been a reef of coral. On the coast of Durham beds of this structure appear associated with masses of brecciated limestone, but very irregularly, and under circumstances not easily explained, without sup-

posing the deposits to have been subject to repeated local and violent disturbance.

Certain beds of this rock in Yorkshire and Derbyshire are very compact; in Durham some are composed of numerous thin, incoherent layers. In several places North of the Dun and near Tadcaster oolitic portions are distinguishable.

But by far the most plentiful of all the varieties of this changeable rock, especially to the North of the river Wharfe, is a loose earthy mass of indistinct beds, with hollow geodes of crystallized carbonate of lime, and numerous veins or strings of the same substance, dividing the rock into angular cells, and helping to hold it together. This character of crystallized cavities and spurry strings is very common to the whole formation, and we occasionally find oxydulated iron, sulphate of strontian, or sulphate of barytes in these cavities. In the quarries at Weldon occur layers of silicious nodules, analogous to the chert lumps in limestone, in oolite, and green sand, and to the flints in chalk. Veins of sulphate of barytes cross the magnesian limestone in several places near Ferrybridge, and near Wetherby. Galena occurs in it at Mansfield and at Warmsworth near Doncaster in small veins, and in other places in detached crystals, as does also sulphuret of zinc; carbonate of copper lines some joints of the rock at Newton Kyme near Tadcaster, at Warmsworth, and at Farnham near Knaresborough; muriate of soda has been obtained by Mr. Holmes from the red beds of Mansfield, and a solitary lump of red rock salt was found in connection with it near Pontefract.

Organic remains of retеporæ, crinoidea, brachiopodous bivalves, and other shells of mollusca, occur in this rock, in by far the greatest abundance near Sunderland in Durham; they are much less plentiful in the upper parts of the rock in Yorkshire between the Dun and the Wharfe; and only a few species obscurely show themselves in Derbyshire and Nottinghamshire. There is a great analogy between the organic remains in the magnesian limestone of Durham, and those of the older carboniferous limestone, and it especially deserves attention that in this rock the genus producta is seen for the last time as we ascend the series of strata, while no ammonite has yet been found in it.

Above the yellow magnesian limestone is a series of gypseous red and white marls, fifty feet thick or more, and this is surmounted by the upper laminated limestone.

Upper laminated limestone.

This rock is not coextensive with the yellow limestone, but has a more limited range, scarcely extending beyond the boundaries of Yorkshire. It is most fully developed in the tract between Tadcaster and Tickhill, and may be examined advantageously at Brotherton and Knottingley, where enormous quantities of it are burned annually to lime for agricultural purposes.

It here reaches to about fifteen yards in thickness, and is composed of a vast number of small irregular layers, separated more or less by partings of marl, and obscurely united into uneven and often undulated beds. The stone is nearly devoid of magnesia, its substance is usually compact, so as even to fit it imperfectly for the purpose of lithography; it is remarkably full of dry cracks, which have dendritical faces, and small cavities lined with crystallized carbonate of lime appear in the thicker layers. The thickness of the layers increases suddenly, or the beds become more consolidated toward the bottom, and in this part the crystallized cavities become more numerous and larger, the stone is less compact, holds more magnesia, and is of no value for lime. The prevalent colour of the stone is a smoke-grey, which is often disposed in spots or stripes, and the separating marls are generally light grey, but often purplish, and further South reddish.

Organic remains occur but very rarely, and in the lower beds only. They are very imperfect in general, but appear to be of the same species as others from the yellow limestones of the same vicinity.

Further North, at Nosterfield, these beds change their aspect considerably, so as to resemble closely some kinds of carboniferous limestone, a resemblance increased by the presence of productæ, and the occurrence of galena. About Doncaster this rock assumes a redder aspect, and contains some beds full of magnesia. It is then said to be a *hot lime*, and like the product of the yellow limestone, is injurious if laid on the land in large quantity.

The stony beds mentioned in the general classification of the saliferons system occur at a few points about Gainsborough in Lincolnshire, and Tuxford in Nottinghamshire, as we learn from Mr. Smith, who distinguishes it by the provincial title of *waterstone;* and perhaps the hard white beds at Newnham in Gloucestershire may be referred to the same rock. Its course remains to be further traced, and deserves attention as perhaps affording a term of comparison with the magnesian layers described by M. Elie de Beaumont in the variegated marls of Alsace.

Rock salt.

The following abstract of Mr. Holland's Paper in the *Geological Transactions*, vol. i., will convey a good notion of the situation and mode of deposition of the rock salt in Cheshire.

Character of the country.

Cheshire unites with the Southern part of Lancashire and the Northern part of Shropshire into a great plain, fifty miles long from North to South, and about twenty-five or thirty wide. It is bounded on the East and on the West, and interruptedly on the South, by carboniferous ranges of hills; and the internal area is divided by two ranges of rising ground into three minor plains, which serve to conduct the Dee, the Weaver, and the Mersey to the Irish Channel. The range of Delamere Forest on the West, and an undulated tract ranging nearly Westward to Halton and Runcorn, define the drainage of the Weaver, and include the most abundant sources of salt. Scarcely any rock salt is found except in this limited tract. On approaching the estuary of the Mersey, the ridges which bound the plain approach one another at two points, and suggest the idea of the included plain having been once a lake.

The salt which lies under this plain is found to thicken, at least partially, toward the contraction of the valley; it does not, however, lie beneath the whole surface of the low ground, nor indeed in one connected mass, but occurs in detached masses of limited area. The rock salt of Northwich ranges North-East and South-West, and its breadth is about three-quarters of a mile. The upper bed is thickest on the North-West, and thins off toward the South-East.

Two beds of salt at Northwich, &c.	Three beds at Lawton.
Rock salt.. 20 to 30 yards.	42 yards marl, &c.
Parting of marls, &c. } 11 yards.	4 feet salt.
Rock salt 35 yards known.	10 yards marl, &c.
	12 feet salt.
	15 yards marl, &c.
	24 yards salt.

The upper bed has been worked through only at North-

wich and Lawton. No marine exuviæ occur over the salt, or in any way associated with it. The purest part of the salt in the upper bed is about three or four yards above the bottom of the bed, and about four feet in thickness; the purest part of the lower bed is twenty or twenty-five yards deep in it, and five or six yards thick, below which the salt becomes earthy as above. This is the part worked. The salt is not stratified, but divided into vertical prisms of various polyhedral forms, and different magnitudes, sometimes a yard or more in diameter. The sides of these prisms consist of pure white salt. Gypsum abounds in the marls associated with the salt, the most abundant variety being the fibrous kind.

Mr. Holland supposes that what is now the salt field was once a salt-water lake, separated from the sea by a natural dam; that the evaporation of the water caused the precipitation of the salt, and that it was afterwards covered with the laminated marls. To account for so much salt, he imagines that the sea might often overpass the dam.

Perhaps we may say that there was here a lake of salt water, of which the deposit went on gradually, and that at intervals violent floods filling it with muddy matter, this was precipitated with gypsum, but without salt, but that afterwards the water again subsiding, salt fell as before. If the floods came in from the sea, this might explain the correspondence in character of these gypseous marls, and those which elsewhere belong to the Keuper era.

Section. Northwich.

No.	yds.	ft.	in.	
1	5	0	0	Calcareous marl.
2	*1	1	6	Induated red clay.
3	2	1	0	*Indurated blue clay.
4	1	2	0	Argillaceous marl.
5	0	1	0	*Indurated blue clay.
6	*1	1	0	Red clay with sulphate of lime irregularly intersecting it.
7	1	1	0	*Indurated blue and brown clay, with grains of sulphate of lime interspersed.
8	4	0	0	Indurated brown clay, with much sulphate of lime crystallized in irregular masses.
9	1	1	6	*Indurated blue clay laminated with sulphate of lime.
10	1	1	0	Argillaceous marl.
11	1	0	0	Indurated brown clay laminated with sulphate of lime.
12	1	0	0	*Indurated blue clay laminated with sulphate of lime.
13	*1	0	0	*Indurated red and blue clay.
14	1	0	0	Indurated brown clay, with sand and sulphate of lime irregularly interspersed through it. The fresh water (360 gallons per minute) finds its way through holes in this stratum, and has its level at 16 yards from the surface.
15	1	2	0	Argillaceous marl.
16	1	0	9	*Indurated blue clay with sand and grains of sulphate of lime.
17	5	0	0	Indurated brown clay with a little sulphate of lime.
18	0	1	6	*Indurated blue clay with grains of sulphate of lime.
19	2	1	0	Indurated brown clay with sulphate of lime.
20	25	0	0	Rock Salt.
21	10	1	6	Layers of indurated clay with veins of rock salt (occasioned by water filtering) running through them.
	76	1	9	
22	36	0	0	Rock Salt sunk into 35 or 36 yards.

English Geologists have, till lately, commonly believed that rock salt was the peculiar production of the red marl and red sandstone; but the mines of Wielitzka are in green sand, those in the Salzburg Alps in limestone of the oolitic period.

By far the larger proportion of ordinary springs, from whatever strata they issue, yield muriate of soda, sometimes in very large quantity, and it is important to know that bromine and iodine, which are stated to be always existent in the actual sea water, very generally accompany the muriatic salts in common springs. This is most remarkably the case with bromine. (See *Phil. Trans.* 1830.) The rock salt of Cheshire is perhaps entirely devoid of bromine and iodine, though the brine springs of the same district are found to contain both. The reason of this may be that the hydrobromic and hydriodic salts have not the same ratio of solubility as the muriate of soda.

Saliferous System of Europe.

General view.

We are now at liberty to consider the characters of the saliferous system as they appear in the other parts of Europe, which have been accurately examined by Geologists. This comparison is much facilitated by the mutual understanding now so general between English and foreign observers, and the subject is made familiar to our countrymen by the published inferences of Sedgwick, Voltz, and De Beaumont. The Rhine in its Northward course from Basle divides into two unequal parts an immense area, in which the saliferous system mantles round the primary ranges of the Vosges, Schwartzwald, Odenwald, Spessart, Thuringerwald, and Harz mountains. The natural boundaries of this irregular area, are, on the West, South, and South-East, the French, Swiss, Swabian, and Bavarian ranges of Jura limestone; on the North-West, the slate formation of the Ardennes, Nassau, and Westphalia; on the North the tertiary plains of Northern Germany. Over all this immense tract, the saliferous system contains a calcareous stratum at present unknown in Britain, called the Muschelkalk, a rock which, in some of its external characters, particularly its smoke-grey colour, and association with marls, bears a considerable analogy to the upper layers of the magnesian limestone formation of England, but by the occasional abundance and general character of its organic remains is strongly assimilated to our lias.

Organic remains.

In several districts different portions of the sandstones and marls contain organic remains both animal and vegetable, which are entirely distinct from those yet known to belong to the older formations, but greatly resembling those of the lias and oolites, so that the foreign localities of the new red sandstone series supply us with those links in the chain of general Geological facts which are wanting in Britain, and for want of which English Geologists have been accustomed to view in too absolute a light the distinction between the carboniferous and the oolitic formations. On the other hand, in the greater part of the saliferous system on either side of the Rhine, beds corresponding to the magnesian limestone of England are entirely unknown. It is chiefly along the line of the South-Western face of the Thuringerwald, prolonged to the North-West as far as Münden, in the drainage of the Weser, along the Southern and Eastern borders of the Harz, and on the North-West side of the slate formation connected with the Erzgebirge, in the drainage of the Elster, that the zechstein and rauchwacke represent on a greater scale the yellow magnesian and upper laminated limestone of the North of England.

Salt which, as above explained, occurs in England in beds only in the variegated marls, is found in one or other side of the Rhine in every bed of the system.

From these remarks it is evident that there is a great general resemblance between the characters of the saliferous formation as it exists in Germany, France, and England; but to make the differences equally apparent, it will only be necessary to fix our attention upon two districts in particular, *viz.*, the Vosges mountains, which range to the North-East parallel to the Rhine, and the district in the North-East of Upper Germany, adjoining the Thuringerwald and the Harz mountains.

The general succession of strata in the saliferous system round the Vosges mountains may be well seen on the road from Metz to Strasburgh; and the minuter details of the beds have been ascertained by those eminent Geologists, Voltz and Elie de Beaumont; to the former of whom we owe the discovery of most of the vegetable fossils of these rocks, and to the latter a valuable discussion of the relations of the formations.

Between the bottom of the oolitic system and the top of the saliferous system occurs, about Luxemburg especially, a peculiar sandstone, which has hardly been distinctly recognised in any other situation. Below this, in descending order, is the following series of strata.

Section of the Vosges.

4. Variegated marls, Keuper of Germany, marnes irisées of France.—Red, pale blue, greenish, &c., with gypsum occasionally interstratified, especially near the top, with beds of sandstone of different kinds, containing plants of the families calamites, equisetaceæ, lycopodiaceæ, coniferæ, cycadeæ, &c., univalve and bivalve shells, remains of saurians and chelonida.

In these coloured marls, above the middle, lies a regular bed (six to ten feet thick) of extremely compact magnesian, yellow limestone, without fossils, and under it, in several places, black schistose marls; in this part, also, gypsum is especially abundant. In several situations, thin bands of reddish limestone occur, alternating with anhydrite.

3. Muschelkalk.—Limestone, generally compact, of a light grey or smoky colour, with partings of marl, containing peculiar encrinites, with ammonites, plagiostomata, and other shells analogous to those of the oolitic system, and remains of reptiles. Near Luxemburg it is very thin, and may easily be mistaken for lias; near Saverne it is much thicker, and more characteristic. At Bourbonne les Bains it is a true magnesian limestone. As before observed, it does not exist in England.

2. Variegated red sandstone. (*Bunter sandstein* of Germany, *grès bigarré* of France)—Extremely similar to the new red sandstone of England. This also contains, locally, abundance of organic remains, both animal and vegetable.

1. The strata above named rest, in some places unconformably, upon a vast thickness of red sandstone, in general much coarser, and more like a conglomerate than the variegated red sandstone; the pebbles of quartz, which it contains in abundance, appearing to be derived from the ruins of portions of the primary rocks of the range of the Vosges. The magnificent precipices down which the road descends to Saverne, among grand old woods and torrents, are formed by this rock, and the resemblance which it bears to the old red sandstone conglomerate of Monmouthshire, is such as to bias the English Geologist strongly in favour of that approximation. In other cases, and especially in hand specimens, this rock appears to resemble the coarse red sandstone of Dumfries-shire and of Penrith Beacon, and as these rocks certainly overlie the carboniferous series, this comparison may, perhaps, be exact. The Northern part of the Vosges mountains being wholly composed of these grit rocks, and coal beds being found at many points in the same vicinity, the incumbency of the red sandstone upon the coal is satisfactorily proved.

The lower part of this thick arenaceous group, which rests upon the coal series, is usually of a friable and fragmentary nature, containing admixtures of porphyritic masses, which strongly assimilate it to the red sandstone conglomerate of Exeter, and the red sandstone, expressively so called, of the North of Germany. The upper part, also, gradually becomes finer grained, and more like the ordinary variegated red sandstone; but as in several places this latter rock rests unconformably upon the other, we are justified in adopting the opinion of Voltz and De Beaumont, that it is a portion of the red sandstone series, almost peculiar to the Vosges mountains, and may, therefore, be characterised as the *grès des Vosges*.

North-East of Germany.

The North-East of Germany gives us the following section of the saliferous system.

5. Variegated marls (*Keuper, marnes irisées*) with gypsum, and the usual characters of the strata.

4. The muschelkalk, much as it occurs about the Vosges. It admits of subdivision into two, or, perhaps, three parts, which, according to Hoffman, may be distinguished by their respective types of organic remains.

3. Variegated sandstone. (*Bunter sandstein, grès bigarré.*)

2. Zechstein, or magnesian limestone formation, consisting of the following members:—

a. Rauchwacke, asche, stinkstein, &c. with gypsum.
Coloured marls.
b. Kupferschiefer and zechstein.

1. Lower red sandstone, (*Rothetodteliegende, grès rouge,*) which is often associated with porphyritic masses like the red sandstone of Exeter.

The following Table will show the relations of the three tracts.

England.	France.	Germany.
4. Variegated marls.	5. Marnes irisées.	5 Keuper.
	4. Muschelkalk.	4. Muschelkalk.
3. Variegated sandstone.	3. Grès bigarré.	3. Bunter sandstein.
2. Magnesian limestone.	....	2. Zechstein.
1. Lower red sandstone.	2. Grès des Vosges. 1. Grès rouge.	1. Rothetodteliegende.

A more minute analysis of the zechstein and magnesian limestone series furnishes the following comparison.

England.	Germany.
Upper laminated limestone.	Stinkstein, Rauchwacke, &c.
Gypseous coloured marls.	Coloured marls and gypsum.
Yellow magnesian limestone.	Zechstein.
Marl, slate, and fishes, or limestone with shells.	Kupferschiefer, and fishes of Mansfeld.
Lower red sandstone.	Rothetodteliegende. (Upper part.)

Coal formation.

And we might by a diagram express the gradual change from one of these types to another, putting the Vosges section between those of England and Germany.

With respect to organic remains it may be sufficient to remark generally that they are found locally in

abundance in all the members of the saliferous series in Germany and France, while hitherto they have appeared in England confined to the two lowermost groups.

Salt.

It appears that the greater part of the salt beds of Germany occur in the muschelkalk, between Magdeburg and Osnabruck, and in the Valley of the Neckar in Würtemberg. At Vic, Baden, and Lons le Saulnier, salt lies in red marl, along the North side of the Tyrolean alps in red sandstone, (Altenau, Berchtolgaden,) and it is possible that the abundant salt-works on both sides of the Carpathians in Transylvania and Moldavia may be established on this series. The salt of European Russia (Strangways, in *Geol. Trans.*) is also connected with the new red sandstone; but the geological age of the salt amongst the sands (said to be red) of Persia, in India between the Indus and Chellum, in Africa, New Holland, and North America, is at present a matter of conjecture, though in the Valley of the Mississippi we recognise the characters of a red sandstone deposit. The salt of Cordova, in Spain, and various points along the line of the Pyrenees, appears to lie in green sand; that of the Salzburg alps belongs to alpine limestone of the oolitic area, while in Sicily salt is found in sulphureous tertiary marl, and at Wielitzka it lies in tertiary strata containing a few shells.

Circumstances attending the Origin of the Saliferous System.

Its marine origin.

From the preceding statement we may confidently decide that the whole of the strata belonging to the saliferous system were deposited in the sea around the previously elevated lines of older rocks. The mechanical aggregates of sandstone, and clays, and marls, do not in general show us those exceedingly fine laminations and indefinitely numerous alternations of different materials which mark the coal deposits, they do not abound in such a multitude of spoils of the land, nor contain extended layers of the reliquiæ of fresh water. Had he never known of the local accumulations of fossil plants in the Keuper and variegated sandstones of the Continent of Europe, the English Geologist might have consistently doubted whether inundations from the land had ever disturbed the regular operations of the sea during this period. To explain this irregularity of distribution of terrestrial plants, it may be supposed that inundations from the land happened only in particular places along the margin of that ancient sea, or it may be said that the inundations being general, the growth of plants was limited. With respect to the accumulation of the rocks themselves, equal difference of opinion may be indulged; for if the remarkable absence, from the greater part of the area of the saliferous sytem, of any marine exuviæ in the mechanical aggregates might favour the notion of the materials being wholly derived from the land, yet the mere fact of the extraordinary and connected extent, the remarkable *uniformity of character of these extensive deposits*, even where the more anciently elevated strata round which they were evidently formed are of entirely different nature, and their apparent *independence* of these boundaries of their surface, seem to prove either 1. that the materials were collected by the action of the sea itself; or 2. that when brought into it by other agents, they were for very long times exposed to its equalizing action.

This long action of the waves upon the particles of the silicious and aluminous rocks and minerals which compose the mechanical aggregates and sedimentary deposits of the saliferous system, is also suggested by the amazing prevalence of the colour of peroxide of iron, which covers as a varnish so many of the particles; and it is confirmed by the discoveries of the organic remains, since these are of such a nature as to prove that during the saliferous period the whole living creation of the carboniferous period came to an end, and was replaced by several peculiar tribes which likewise finished their career and yielded to the more numerous races which fill the oolitic rocks.

Prevalence of magnesia.

The calcareous portion of this system presents us with even more decisive evidence, from its organic remains, of its marine origin, but the circumstances which permitted the accumulation of the magnesian carbonates of lime are in great measure unknown to us. That they were originally deposited in the same chemical condition as we now see them, without the subsequent aid of any igneous operations, is perfectly evident; and the occasional occurrence of *pebbles and shells* of the carboniferous system in the magnesian limestone, coupled with the known fact that certain beds of the carboniferous limestone contain a large proportion of magnesia, might lead us to conjecture that the one is derived from the ruins of the other. But, as Professor Sedgwick observes in discussing this subject, (*Geological Transactions*,) all the magnesian beds in the carboniferous limestone would be quite insufficient for the purpose, and the *crystalline character* of the Mansfield and other varieties of magnesian limestone clearly negatives this mechanical solution. Beds rich in magnesia alternate with others devoid of that substance, the same beds are in one tract magnesian, in another yield pure lime, and in general we must be content to shelter our ignorance under the statement that from some unknown cause the waters of the sea were then decomposed in such a way as to permit very generally the precipitation of united magnesian and calcareous carbonates—the possible circumstances of which must be intrusted to the examination of the Chemist.

Salt and gypsum.

The salt and gypsum usually associated in this remarkable system present also their difficulties. Not that it is hard to suppose the waters of the ancient sea to have been so evaporated as to permit first the crystallization of sulphate of lime, and finally of muriate of soda. But in this case we should expect to find almost uniformly over the whole area regular strata of gypsum below, and regular layers of salt above, while, in fact, we more commonly find salt in great broad masses rather than beds below, and gypsum in scattered masses above. A general drying of the waters in which the saliferous system was deposited is plainly inconsistent with probability; and we must have recourse to local causes, something analogous perhaps to those which influenced the deposit of primary limestone. It may be conceivable that the solubility of muriate of soda in water is capable of diminution through the admixture of other substances in the liquid, or through the effects of great pressure, or of pressure and heat combined; it may be maintained that the limited deposits of salt happened in separated lagunes of the sea, exposed to local desiccation, as perhaps in Cheshire. Mr. Lyell has still a different and less probable view of the subject. All these explanations assume that the salt was produced directly by *mere* crystallization, from waters almost perfectly analogous to those of the actual seas; an assumption strongly confirmed

by the recent discoveries connected with bromine and iodine.

Further researches, both Chemical and Geological, must determine between these and other theories, and in particular, we must be more exactly informed of the ancient hydrography of the salt districts, which, in almost every instance, must have been very different from their present topographical features.

Table of the Organic Remains of the Saliferous System.

The asterisk distinguishes such as are known to occur in other systems of strata.

PLANTS.

Family.	Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Pœcilitic Sandstone.	Locality in Magnesian Limestone.
Algæ	Fucoides Brardii				Frankenberg copp. slate.
	selaginoides				Mansfeld, ditto.
	frumentarius				Ditto.
	pectinatus				Ditto
	digitatus				Ditto.
	lycopodioides				Ditto.
Cryptogamia	Equisetum Meriani	Neue Welt near Basle.			
	*columnare	Würtemberg		Sulzbad, or Soultz.	
	platyodon	Franken in Würtem.			
	Calamites arenaceus	Ditto		Wasselone, Marmoutier.	
	Mougeottii			Marmoutier.	
	remotus			Wasselone.	
	Pecopteris Meriani	Neue Welt.			
	*arborescens				Near Autun.
	*abbreviata				Ditto.
	Tæniopteris *vittata	Neue Welt, Stuttgart.			
	Anomopteris Mougeottii			Soultz, Wasselone.	
	Neuropteris Voltzii			Soultz.	
	elegans			Ditto.	
	Gaillardoti		Luneville.		
	Sphænopteris myriophyllum			Ditto.	
	palmetta			Ditto.	
	Filicites Stuttgartensis	Stuttgart.			
	lanceolata	Ditto.			
	scolopendrioides			Ditto.	
	Lycopodites Hœninghausii				Eisleben near Mansfeld.
Cycadeæ	Pterophyllum longifolium	Neue Welt.			
	Meriani	Ditto.			
	Jægeri	Franken, Stuttgart.			
	enerve	Neue Welt.			
	Mantellia cylindrica		Ditto.		
Various families.	Convallarites erecta			Ditto.	
	nutans			Ditto.	
	Palæoxyris regularis			Ditto.	
	Echinostachys oblongus			Ditto.	
	Æthophyllum stipulare			Ditto.	
	Marantoidea arenacea, Jæger.	Stuttgart.			
	Voltzia brevifolia			Ditto.	
	elegans			Ditto.	
	rigida			Ditto.	
	acutifolia			Ditto.	
	pterophylla			Ditto.	
	Asterophyllites ? bullosa				Thuringerwald.

The following plants, which are well known in the coal strata, occur in the lowest red sandstone. (Rothetodteliegende.)

*Lepidodendron Sternbergii	Hinkelheim in the Spessart.
*imbricatum	Werderbruck near Rothenburg.
*Stigmaria Veltheimiana	Magdeburg ?

Other vegetable relics at Amrode, Seibigkerode, between Friedeburg and Rothenburg, Kyffhaeuser, Meisdorf, Endorf.

The names in this list are taken from M. Brongniart, who supposes the flora of the variegated sandstone system to be of a peculiar type. It is certainly very analogous to that of the succeeding or oolitic epoch, by its pterophylla and equiseta, but the genus Voltzia is perhaps peculiar to it.

POLYPARIA.

Name.	Locality in Magnesian Limestone.
Gorgonia anceps, Goldfuss.	Glücksbrunn in Thuringerwald.
antiqua, G.	Glücksbrunn.
infundibuliformis, G.	Ditto.
*Calamopora spongites, G.	Ditto, (and Ural.)
Retepora flustracea, Phil.	Durham.
virgulacea, Phil.	Ditto.
Astræa pediculata, D.	

The absence of polyparia from the muschelkalk is one of the characters by which it approximates to the lias.

Radiaria.

Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Magnesian Limestone.
Ophiura prisca, Mün.	Vosges Mountains	Baireuth.	
loricata, G.	Schwenningen.		
Asterias obtusa, G.		Marbach.	
Encrinus moniliformis, Mil.		General in this rock.	
ramosus, Schl.			Glücksbrunn.
Pentacrinus dubius, Gold.		? Rudersdorf.	
*Cyathocrinus planus, Mil.			Durham.

Annulosa.

Name.	Locality in Muschelkalk.
Serpula valvata, G.	Baireuth.
colubrina	?

By its radiaria, amongst which no echinus is mentioned, the muschelkalk resembles the lias; those radiaria which lie in the magnesian limestone present greater analogies to the older rocks.

Conchifera.

Family.	Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Pœcilitic Sandstone.	Locality in Magnesian Limestone.
Plagymyona.	Cardium pectinatum, v. Alberti	Wurtemberg	Würtemberg.		
	striatum, Schl.		Ditto, Göttingen.		
	Trigonia vulgaris, Schl.	Ludwigsburg	Weimar, Göttingen, Würtemberg, Baireuth	Domptail, Soultz.	
	curvirostris, Schl.	Ditto, Schwenningen.	Würtemberg.		
	sulcata, G.	Villingen.			
	pes anseris, Schl.		Göttingen, Morsbach, Luneville.		
	cardissoides, G.		Würtemberg.		
	lævigata, G.		Marbach.		
	Goldfussi, v. Alberti		Ditto.		
	Mya musculoides, Schl.	Sultz on the Neckar	Weimar, Würtemberg, Upper Silesia, Poland	Sulzbad.	
	elongata Schl	Ditto ditto	Würtemberg, near Waldshut, Upper Silesia, Poland	Sulzbad.	
	ventricosa, Schl.		Wurtemb Luneville.		
	mactroides, Schl.		Marbach, Upper Silesia, Poland.		
	rugosa, v. Alberti		Rottweil.		
	Modiola minuta, G.	Rottweil.			
	acuminata, Sow.				Durham.
	——— Sedg.				Aberford, Durham.
	Mytilus vetustus, G. eduliformis, Schl.		Gottingen. Würtemberg, Luneville, Baireuth	Domptail, Sulzbad.	
	? keratophagus, Schl.				Glucksbrunn.
	? striatus, Schl.				Ditto.
	squamosus, Sow.				FerrybridgeYorkshire.
	VenericardiaGoldfussi v.Alberti	Rottweil.			
	Saxicava Blainvillii, Hæn.	?			
	Venus nuda, G.		Marbach.		
	——— Sedg.				Durham.
	Mactra ? trigona, G.		Ditto.		
	Axinus obscurus, Sow.				Yorkshire, Durham.
	Astarte ——— ? Sedg.				Whitby, Northumb.
	Arca inæquivalvis, G.		Freudenstadt.		
	tumida, Sow.				Durham.
	Cucullæa minuta, G.		Villingen.		
	sulcata, Sow.				Ditto.

An uncertain bivalve shell is found in the rothetodteliegende at Mansfeld.

Mesomyona.	Plagiostoma lineatum, Schl.	Würtemberg	Morsbach, Michelstadt Gottingen, Würtemberg, Baireuth, Weimar.		
	striatum, Schl.		Very common.		
	rigidum, Schl.		Jena.		
	lævigatum, Schl.		Morsbach.		
	punctatum, Schl.		Göttingen, Gotha, Weimar, Baireuth, Toulon.		
	——— ? Sedg.				Ditto.

Family.		Locality in Keuper.		Locality in Pœcilit[e]	[Lo]cality [in Magnesian] Li[mestone]
Mesomyona. .	Avicula socialis, Schl.	Sulz on the Neckar	Very generally distributed	Sulzbad, Domptail.	
	subcostata, G.	Ditto	Würtemberg, Baireuth.		
	lineata, G.	Ditto.			
	crispata, G.		Friedrickshall.		
	Bronnii, v. Alberti		Villingen.		
	costata			Sulzbad.	
	gryphæoides, Sow.				Durham.
	Posidonia Keuperiana, Voltz	Swabia, Hall.			
	minuta, v. Alberti	Rottweil.			
	Ostrea ?				Whitby.
	placunoides, Mün.		Baireuth.		
	subanomia, M.		Ditto.		
	reniformis, M		Ditto.		
	difformis, Schl.		Wirtemberg.		
	multicostata, M		Würzburg.		
	complicata, G.		Baireuth, Villingen.		
	decemcostata, M.		Baireuth.		
	spondyloides, Schl.		Very general.		
	comta, G.		Rottweil.		
	pleuronectites, Schl.		Bourbonne les Bains, Luneville.		
	Gryphæa ? prisca, G.		Villingen.		
	Pecten reticulatus, Schl.		Göttingen, Gotha.		
	Albertii, G.		Villingen, Rudersdorf.		
	lævigatus, G.		Wurtemberg, Bareuth, Gotha.		
	discites, Schl.		Wurtemberg, Pohlen, &c.		
	Perna vetusta, G.	Dürrheim.			
Brachiopoda .	Lingula tenuissima, Bronn	Rottweil	Rottweil.		
	Orbicula speluncaria, G.				Glücksbrunn.
	Terebratula communis, Bosc. vulg. et subrot. Schl.		Göttingen, Wirtemberg, Luneville, Bourbonne les Bains, Toulon.		
	perovalis, Schl.		Jena.		
	sufflata, Schl.		Ditto		?
	orbiculata, Schl.		Near Jena.		
	cristata, Schl.				Ropsen.
	elongata, Schl.				Schmerbach.
	complanata, Schl.				Gera.
	intermedia, Schl.				Ropsen, Schmerbach.
	inflata, Schl.				Ditto, ditto.
	lacunosa, Schl.				Ditto, ditto.
	paradoxa, Schl.				Schmerbach.
	pelargonata, Schl.				Ditto.
	pygmæa, Schl.				Lemnstein near Schmalkalden.
	several species				Durham.
	Delthyris, spirifer, Sow. semicircularis, G.		Villingen.		
	trigonalis, Sow.				Ropsen.
	undulatus, Sow.				Durham.
	multiplicatus, Sow.				Ditto.
	minutus, Sow.				Ditto
	Leptæna, or Producta aculeata				Thaltter, Goldelsheim, Budingen, Logan am Queiss, Durham.
	speluncaria, Schl.				Ropsen, Glucksbrunn
	rugosa, Schl.				Ropsen.
	antiquata, Sow.				Durham.
	calva, Sow.				Ditto.
	spinosa, Sow.				Ditto
	*longispina ? Sow.				Schmerbach.

N.B. A species of terebratula ? is found in the rothetodteliegende at Mansfeld.

The general result of an examination of the fossil conchifera of the saliferous system, is, that in the upper strata a general analogy to the oolitic era can be recognised by the trigoniæ, plagiostomata, ostreæ, &c. ; and in their productæ and spiriferæ the lower strata as distinctly claim affinity with the carboniferous *limestone*.

Gasteropoda.

Family.	Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Pœcilite Sandstone	Locality in Magnesian Limestone
Holostomata .	Calyptræa discoides, Schl.		Villingen.		
	Capulus, or Pileopsis mitratus, G.		Ditto.		
	Dentalium torquatum, Schl.		Göttingen.		
	læve, Schl.		Ditto, Alpirsbach, Baireuth.		

Family.	Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Pœcilitic Sandstone.	Locality in Magnesian Limestone.
Holostomata	Trochus albertinus, G.		Rottweil.		
	Pleurotomaria ?				Durham.
	Turbo ? dubius, Mün.		Seewangen. Riedern, near Waldshut.		
	? giganteus, Schl.		Seewangen.		
	?				Yorkshire, Durham, Derbyshire.
	Turritella obsoleta, Schl.		Weimar, Göttingen.		
	deperdita, G.		Weimar.		
	detrita, G.		Culmbach.		
	scalata, Schl.		Wurtemberg, Rudersdorf.		
	? terebralis, Schl.		Weimar	Domptail, Sulzbad.	
	Scholteri			Sulzbad.	
	undescribed				Yorkshire.
	Melania				Durham.
Solenostomata	Buccinum turbilinum	Sulz on the Neckar.	Wurtemberg, Seewangen, Rüdersdorf.		
	gregarium, Schl.		Rudersdorf.		
	antiquum, G.			Sulzbad.	

Cephalopoda.

Name.	Locality in Muschelkalk.
Nautilus bidorsatus, Schl.	Weimar, Rüdersdorf, Gottingen, Würtemberg, Luneville.
nodosus, Mün.	Franken.
Ammonites nodosus, Schl.	Weimar, Göttingen, Würtemberg, Lorraine, Toulon, Tarnowitz.
bipartitus, Gall. / semipartitus, Schl.	Luneville.
Rhyncholites Gaillardoti d'Orb.	Jena, Gottingen, Würtemberg, Luneville, Rehainvillers.
hirundo, Fauv.	Wurtemberg, Luneville.

These cephalopoda are characteristic of the muschelkalk. The ammonites belong to a section of that numerous genus, distinguished by peculiar sutures. (See Von Buch's Essay on the subject of the sutures of ammonites. (*Ann. des Sci. Nat.*)

Crustacea.

Name.	Locality in Muschelkalk.
Palinurus Sueurii, Desm.	Villingen, near Saarbrück.

Verterbralia.

Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Magnesian Limestone.
Fishes	Seidmannsdorf, Nenses, Seidingstadt, near Coburg.	Baireuth.,	
Palæothrissum, Blain.			
P. macrocephalum, Bl.			Mansfeld, Durham
magnum, Bl			Ditto, ditto.
inæquilobum, Bl.			Rothenburg, near Autun.
macropterum, Bronn.			Thüringen.
parvum, Bl			Rothenburg, near Autun.
blennioides, Hall.			Mansfeld.
elegans			Durham.
Freislebense, Bl			Mansfeld, Hesse.
Stromateus major, Bl.			Hesse.
gibbosus, Bl			North of Germany.
Clupea Lametherii, Bl.			Eisleben.
?			Seefeld in Tyrol.
Chætodon ?			Durham.
Other fishes			Seefeld.
Teeth of Squalus Raja	Wurtemberg	Wurtemberg, Rudersdorf.	

These remains of fishes lie in marl or copper slate at the bottom of the zechstein and magnesian limestone formation.

Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Magnesian Limestone.
Phytosaurus cylindricodon, Jæg.	Boll.		
cubicodon, Jæg.	Ditto.		
Mastodonsaurus Jægeri, Holl.	Gaildorf.		
Ichthyosaurus Lunevillensis	Würtemberg	Luneville, Würtemberg.	
Plesiosaurus	Dürrheim	Würtemberg, Baireuth, Rüdersdorf.	
Crocodilus		Rüdersdorf.	
Monitor antiquus, Cuv.			Mansfeld. Rothenburg, Glücksbrunn.
Large saurian		Luneville.	
Chelonia		Ditto. Bindlocher, and Leineckerburg.	

GENERAL SUMMARY.

Plants......	Marine....................	6;	wholly confined to the zechstein.
	Cryptogamia	23;	of which six are stated to occur in other systems of strata.
	Gymnosperma, &c.........	17.	
Zoophyta ...	Polyparia	7;	all confined to the zechstein group; one found in another system of strata.
	Radiaria	7;	confined to the muschelkalk and zechstein; one repeated in carboniferous limestone.
Articulosa...	Annulosa	2	in muschelkalk.
	Crustacea	1	
Mollusca....	Conchifera plagymyona	32;	eight of these occur in England in magnesian limestone.
	mesomyona	32;	three of these occur in England in magnesian limestone.
	brachiopoda	28;	eight of these occur in England in magnesian limestone.
	Gasteropoda holostomata ...	17;	four of these occur in England in magnesian limestone.
	solenostomata	3.	
	Cephalopoda..............	6.	
Fishes	....	15;	four occur in England in magnesian limestone.
Reptiles	....	9.	
		205;	of which about thirty occur in England in magnesian limestone.

Disturbances of the Saliferous System.

In England dislocations of a very extensive nature are but rarely exemplified in strata more recent than the coal measures. It appears that this part of the surface of the Globe enjoyed a long and rarely interrupted immunity from those violent agencies which had previously shaken its strata into such disturbed positions. A few faults in the magnesian limestone range of Durham and Yorkshire, as along the line of the great whindyke through those Counties, in the country between Doncaster and Ferrybridge, and South of Doncaster, may be mentioned rather as exceptions to the general rule, effected in some indefinite portion of the long period succeeding the deposit of coal; and the curious parallel faults of Aust cliff on the Severn, which affect both the lias and red marl, deserve attention, in connection with the law formerly laid down of faults underlying depressed portions of strata. (p. 511.)

Neither on the Continent of Europe are the dislocations of the saliferous system so remarkable as those of the older strata. In the Vosges mountains we have, however, a splendid example of a dislocation on a great scale, by which, in a direction North-East and South-West, the lower strata of this system (*grès des* Vosges) are thrown up into bold mountains, while the upper beds of the same system (muschelkalk and keuper) are left several hundred feet below the magnificent escarpment. In fact, it appears that this eruption happened during the saliferous epoch, after the date of the grès des Vosges, and before the muschelkalk and keuper were deposited.

In the South-West of Brittany, in La Vendée, in Morvan, De Beaumont describes dislocations which appear to have preceded the lias; and from observations on the Böhmerwald and Thuringerwald it appears that the elevation of these ranges of mountains followed the saliferous epoch, and preceded the lias and oolites. Of the same era are some dislocations defining the primary ranges near Avallon and Autun.

Several cases, then, appear to show unconformity and interruption of continuity between the variegated marls and the oolitic formation above. But these are but local effects; parallelism of strata generally prevails between these contiguous systems, indicating freedom from general disturbance, and in some instances, especially in Somersetshire, the frequent changes of colour in the upper red marls, and finally the interposition of a purple or black marl, which is not more related to the lias than to the saliferous system, appear to show that even in the nature of the deposits there is no more decided difference between them than between any other successions of strata.

Oolitic System.

The oolitic system of strata has for the most part its ranges parallel, and its declinations accordant to the saliferous rocks, and was deposited in the same marine basins. The general character of the rocks, and the nature of the organic remains is however extremely different, but the change from the one system to the other, though seldom to be called gradual, is accomplished by remarkable repetitions. In particular, the muschelkalk of Germany and France represents, even in mineralogical characters, but most decidedly in its suite of organic exuviæ, the lias, which is at the base of the oolitic system. Through all the mass of the oolitic system, consisting of various limestones, clays, and sands, the most remarkable repetitions occur. The mass of lias contains beds very nearly approaching to the ferruginous inferior oolite; three or four separate beds of very similar oolite, several beds of sand and sandstone also remarkably analogous, and many thick strata of clay hardly distinguishable except by their organic reliquiæ, make up this vast argillo-arenaceo-calcareous mass, of which the top changes, by repeated introductions of green sand layers, to the real cretaceous system, as the bottom has been before shown to be connected with the saliferous group.

The composition of this system varies much in different Countries of Europe, according, probably, to the differences of depth of the original waters, proximity to land, to mouths of ancient rivers, &c. In consequence, while on the border of Swisserland it is almost wholly calcareous, in Westphalia and in England its limestones are much intercalated with clay, and occasionally with carboniferous sandstones and shales, hardly to be distinguished from those of the older coal strata. A remarkable absence of metallic substances is a character of the calcareous portions of this system (excepting the lias) in all its extent.

The most distinct classification of the oolitic system will be obtained from the combined section of the English series; for though the total thickness of the deposit is perhaps greater in the South East of France and in Swisserland, the number of divisions is there less, the mass more uniformly calcareous, and the parts less characteristic.

The oolitic system of England everywhere admits of

the following mode of subdivision, though in some tracts particular groups are concealed by unconformity or entirely wanting. The groups are placed as they occur in nature, or the series is descending.

5. Wealden formation.	A series of clays, sandstones, and limestones, mostly of fluviatile origin, and containing remains of land and fresh-water animals and plants, deposited in estuaries or other local hollows of the really marine portion of the oolitic system.
4. Upper or Portland oolite formation.	Calcareous, sometimes oolitic rocks, associated with green and irony sands, resting on blue clay, altogether marine deposits. When the Wealden formation is absent (as happens in the greater number of instances) this terminates the whole system, and graduates into the cretaceous rocks above.
3. Middle oolite or coralline formation.	Consisting of oolite and other limestone strata, included in calcareous gritstones, and resting on blue clay and calcareous gritstone: altogether marine deposits.
2. Lower or Bath oolite formation.	Consisting of two or more strata of oolite, with other calcareous beds, and alternations of sands and clays, which in particular districts enlarge themselves into real coal tracts. Altogether marine and littoral deposits.
1. Lias formation.	Consisting principally of argillaceous clays, more or less laminated, and including, especially in the lower part, layers and nodules of generally argillaceous limestone, and in the upper part bands and strata ferruginous, calcareous, and arenaceous, which strongly resemble the bottom of the lower oolite formation.

Oolitic System.

A further analysis of these formations presents us with the following details.

5. Wealden formation of Kent, Sussex, and Hampshire.		*Weald clay.* Thick blue clays, generally destitute of organic remains, except in certain calcareous beds, which contain fresh-water shells.
		Hastings' sands. Thick series of sandstones, with partings of clay, and subordinate beds of limestone, with bones of saurians, fluviatile shells, and land plants.
		Purbeck beds. Blue clays and laminated limestones with fluviatile shells.
4. Upper oolite formation of Portland, Wilts, Bucks, Berks, &c.		*Portland oolite.* Oolite and earthy and compact limestones with marine shells, and layers of nodular chert.
		Shotover sand. Calcareous sand and concretions.
		Kimmeridge clay. Thick blue clay, bituminous, with septaria and marine remains, and especially in the lower part, bands of sandy concretions, thus establishing a gradation to the next system.
3. Middle oolite formation of Oxford, Berkshire, Yorkshire, &c.	Coralline oolite group.	Upper calcareous grit, with marine fossils.
		Coralline oolite, so named from two or three separate beds of irregular occurrence, rich in zoophytic exuviæ. In the lower part the beds alternate with those of the next rock; all of them contain marine exuviæ.
		Clay 10 feet. Lower calcareous grit, with marine shells, graduating below into the Oxford clay.
	Oxford clay group.	Oxford clay, with septaria, fossils, &c.; the lower part a subordinate bed, called
		Kelloway rock, which is a calcareous grit, (rarely oolitic,) very rich in fossils.
		Blue clay dividing Kelloway rock from the cornbrash.
2. Lower oolite formation in Gloucestershire, Oxfordshire, and Northamptonshire		Cornbrash limestone, a coarse, shelly rock of variable and small thickness, but remarkable continuity.
	Forest marble group.	Sand with concretions of sandstone and nodules of fissile arenaceous limestone.
		Coarse shelly oolite, in some places slaty.
		Sandy clay or grit.
		Blue clay.
	Great oolite.	A calcareous and mostly oolitic rock, of variable thickness and changeable nature, the upper beds shelly.
	Fuller's earth group.	A series of marls and clays with included beds of soft marly or sandy limestones and shells.
	Inferior oolite.	A coarse, often very shelly rock of limestone, irregularly oolitic, occasionally interlaminated with sand, especially in the lower part.
		Ferruginous sand with concretionary masses of sandy limestone and shells.
1. Lias formation in Yorkshire, Northamptonshire, and Somersetshire.		Upper lias clay or shale, full of belemnites and other fossils, intercalated with or graduating to the sand above, and in some cases containing nodules and bands of limestone.
		Marlstone. A suite of calcareous, sandy, and irony beds, very rich in fossils, and much analogous to the lowest bed of the lower oolite formation.
		Lower lias clay or shale, full of fossil remains, interlaminated with bands and nodules of limestone, especially in the lower part, where a collection of these layers constitutes the lias rock.
		Lias rock. A suite of laminated limestones, with partings of clay, blue, grey, and white, the former in particular containing gryphites and other shells; the latter usually devoid of organic remains. This rock is sometimes consolidated into a united mass, and sometimes divided into separate portions. It rests on the red marl in the North of England, and on blue, black, or purple marls, which cover that formation in the South of England.

N. B. All this part of the series is differently composed in Yorkshire and the North of Scotland.

The lias formation is observed on the Southern coast of England, at Lyme Regis, from whence passing under the unconformable green sand of Blackdown, and surrounding the irregular elevations of carboniferous limestone in Somersetshire, it ranges uninterruptedly by Bath, Gloucester, Leicester, Newark, and Gainsborough, to the Humber. At this point the course of the oolitic system is very much narrowed by the overextension of the chalk; and at Bishop Wilton the chalk rests on the lowest part of the lias formation, which has a superficial breadth of only a few yards. It, however, expands again towards the North, and shows itself very completely developed on the coast of Yorkshire. Detached portions of this formation accompany the saliferous system in Glamorganshire, and lie unconformably in the hollows amongst elevated ridges of carboniferous limestone.

Through the whole of this range some general physical features, almost constant mineralogical qualities, and prevalent species of organic reliquiæ, fix such a decided character upon the lias formation as to establish a good geological horizon for the guidance of the English observer.

The country which it occupies is in general a broad vale at the foot of the escarpments of oolite, and terminating towards the red marl by a very connected range of uniform low hills. A considerable portion of the steep slope of the oolite escarpments is occupied by the lias; and in the Midland Counties, particularly, owing to the action of currents of water, detached portions of

oolite crown the summits of many insulated masses of the upper lias shales.

From the coldness and stiffness of the soil, much of the surface of the lias clays remains in pasture, for which it is particularly well adapted; and where the plough has in former times been employed, the land is thrown up into very high ridges for the sake of surface drainage. Water is scarce in this tract, and, because of the abundance of pyrites, often sulphureous or ferruginous, or impregnated with purgative salts, as sulphate of soda.

A general tendency to an argillaceous type belongs even to the limestones of the lias formation, and its clays more frequently exhibit a schistose structure than the other clays of the oolitic system. Layers and masses of jet are frequent in it, especially in the Northern part of its course; pyrites is one of its most abundant productions, especially in connection with ammonites and other shells, and sulphur in some parts is so prevalent as to furnish a valuable manufacture of alum. Many fruitless trials for coal along the line of the lias clays are upon record, to serve as a warning to those unacquainted with Geology.

Very remarkable organic exuviæ belong almost equally to every part of the English lias. Skeletons of saurian and chelonian reptiles, several species of scaly fishes, abundance of ammonites and belemnites, plagiostomata, gryphææ, &c. and considerable quantities of the wood of coniferous trees, enable the Naturalist to form very reasonable views of the state of the ancient land and sea when this formation was in progress, and serve not only to identify it in all parts of England, but even over a large part of its extent in France and Germany.

Nevertheless, there are important geographical peculiarities connected with the lias of England, which deserve a short analysis, the better to enable us to perceive the circumstances under which the ancient sedimentary deposits of the sea took place.

Lias in Yorkshire.

The section of the lias, as it exists in Yorkshire and Lincolnshire, is peculiarly instructive and complete, and forms an excellent type with which to compare the detached portions of the formation in North Britain and the South of England. We shall take the groups in the ascending order of their antiquity.

Lias limestone. The calcareous beds included in this division are in the North of England very distinctly divided into two or more portions separated by considerable thickness of clay.

1. The lower limestone, 10 to 20 feet thick, is not traced further North than the Humber. It consists of compact blue or grey limestone, generally laminated and shelly, with partings of whitish clay or marl. It rests immediately upon the red marl and gypsum.

2. Clay, 50 to 100 feet, with layers of nodules, often septariate, full of pentacrinites, ammonites, plagiostomata, &c.

3. Upper lias limestone, 12 to 20 feet, in rough, shelly, coarsely laminated beds, separated by partings of clay. The colour usually brown, but in wet pits and before exposure to the air internally blue. But the most remarkable character of these beds is the astonishing abundance of gryphæa incurva which they contain, or rather of which they almost wholly consist. In several parts of Lincolnshire the roads are mended with the most beautiful specimens of this fossil, and for miles together hardly any other shells can be collected from this part of the lias.

Lower lias clay or shale, 300 to 500 feet thick, a dark homogeneous clay or shale, with many layers of argillo-calcareous nodules, seldom containing shells, and in the lower part rough sandy beds. Coniferous wood, pentacrinites, plicatulæ, gryphæa Maccullochii, pinna folium, and several ammonites, &c. occur in this stratum, but in it organic remains are not particularly abundant, and neither belemnites, terebratulæ, nor saurians are so plentiful as in the beds above. No alum is made from this part of the lias shale.

Marlstone series, 100 to 150 feet, consisting of highly arenaceous shales, and laminated sandy limestones of brown, greenish, or grey colour, succeeded above by several bands of nodular ironstone, the whole series particularly abundant in shells, besides producing beautiful stellerida, annulosa, and fishes. Several species of terebratulæ, cardium truncatum, dentalium giganteum, &c. appear almost confined to these strata, which likewise contain gryphææ, pectines, plagiostomata, terebratulæ, and modiolæ, not distinguishable from the ordinary fossils of the oolite. The marlstone beds are in fact the first term of the oolitic deposits, interpolated among the last terms of the lias, and, according as the clay above them is attenuated or developed, they may be ranked with the oolitic, or the lias formation. In the North of England, the former mode of arrangement *must* be adopted, but in the South, the latter has been often followed.

The upper lias clay or shale, 50 to 200 feet in thickness, is the aluminous rock of Yorkshire, and passes by intermixture into the marlstone series below, and by a gradual change into the analogous sandy beds of the oolites above.

It contains a multitude of layers of argillo-calcareous nodules mostly aggregated round ammonites and other organic bodies, and these are particularly remarkable and of larger size in the lower part of the shale, which also is much harder than the rest. A profusion of ammonites, belemnites, and nautili, accompanied by aviculæ, inocerami, amphidesmata, &c., besides abundance of ichthyosauri, and plesiosauri, jet, and remains of coniferous wood, enrich this interesting rock. Its thickness is variable, amounting to 200 feet on the coast, but diminished to 50 feet, or even less, in some of the Cleveland hills, where also the usual smooth homogeneous texture of aluminous shale is changed to a decidedly sandy composition.

Lias in Midland Counties.

Proceeding to the South, we find the characters of the lias formation of Yorkshire maintained with considerable exactness through the Counties of Nottingham, Lincoln, Leicester, and Rutland, into Oxfordshire. The section from Lincoln to Gainsborough shows clearly the upper lias clay, marlstone group, lower lias clay, gryphite limestone, and laminated limestone, all superimposed on gypseous red marl. In the vale of Belvoir, likewise, through Rutland, and as far as the centre of Oxfordshire, we have the lower laminated limestone (1.) surmounted by a thick clay, (2.) in which lie gryphitic beds peculiarly shelly, which Mr. Conybeare calls *upper lias* beds, and which correspond to the gryphitic beds of Lincolnshire. Still higher, are beds of green or brown marly sandstone, with terebratulæ, pectines, belemnites, and other shells, which are always ferruginous, and, in Rutland particularly, laminated and entirely similar to some of the marlstone beds of Yorkshire. Above these, in the same tracts, lie 100 or even more feet of clay, often forming insular

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hills between valleys of marlstone, and upon the whole the ferruginous sand of the inferior oolite.

If any doubt has at any time been raised as to the real distinction in this country of upper lias clay, marlstone, lower lias clay, and double course of lias limestone, it has probably arisen from the extreme resemblance of the ferruginous marlstone of the Vale of Belvoir which divides the upper from the lower lias clay to the ferruginous sandstone which is the general floor of the oolitic rocks. In Rutland, however, the distinction is perfectly evident.

Lias of the Cottswold.

Through Oxfordshire and Gloucestershire the upper lias clay continually becomes thinner, and the marlstone beds in consequence approach nearer to the sand of the inferior oolite. It is no wonder, therefore, that they should be in these Countries sometimes confounded. But the section of Painswick Hill, near Stroud, adduced by Mr. Conybeare, (*Geology of England*, p. 252.) sufficiently proves that the same principle of classification applies to the lias below the Cottswolds, as well as to the North-East moorlands of Yorkshire. In fact, by merely taking the argillaceous beds which in this section separate the sands of the oolite from those of the marlstone, and calling them upper lias clay, the accordance with the Yorkshire section is perfectly evident. This question has been effectually settled by Mr. Lonsdale's recent and most valuable investigation of the Cottswolds. That excellent observer has clearly established the identity of the lias system of Gloucestershire with that of Yorkshire, in general terms; at the same time defining the amount of topographical difference which principally affects the upper lias shale.

In the Southern parts of Gloucestershire, and in the vicinity of Bath, the upper lias clay becomes still more attenuated, and the marlstone beds more divided and mixed with the clay. Mr. Smith gave the name of marlstone to the laminated stony beds full of pectines and other shells which are found in the Somerset canal and other places, twenty feet or less below the sand of the inferior oolite, as may be noticed in his sections. In several places, these beds, from the deficiency of the clay above, are brought nearly into close contact with the sand of the inferior oolite.

Whether this distinction of marlstone beds can be carried further South into Dorsetshire does not yet appear.

From Mr. Lonsdale's Essay in the *Geological Transactions*, we find the lias limestones to be thus arranged in the descending order.

	Feet.
Blue lias. Consisting of beds of greyish argillaceous limestone, varying in thickness from 2 to 18 inches, and separated by others of blue marl which are generally less than 6 inches thick, but sometimes more than 2 feet	50 to 60
White lias. Thin strata of yellowish white argillaceous limestone, with partings of pale brownish clay	10
Lias lower marl. Dark grey marl with calcareous concretions	20

Organic remains of ammonites, belemnites, pectens, oysters, &c. though most abundant in the blue lias, are more or less diffused through all the beds.

Combining the section of the North of England with Mr. Lonsdale's and Mr. de la Beche's sections of the lias in the vicinity of Bath and Lyme, we shall have the following general table of the complete type of the English lias.

1. Upper lias clay, marl, or shale..	Upper lias shale (Phillips.)
2. Marlstone beds.	
3. Middle lias clay	Upper lias marl. (Lonsdale.) Lower lias shale. (Phillips.)
4. Lias limestones and marls ...	Gryphitic and laminated lias of North of England. Blue and white lias of Bath.
5. Lower lias marls	Of Lyme Regis and Bath.

These lower marls are thus described by De la Beche, at Culverhole, near Lyme, (section descending.)

	Ft.	In.
Dark marl	3	0
Earthy dark grey limestone	0	10
Dark grey slaty marl	5	9
Irregular light grey limestone	0	10
Dark slaty marl	1	4
Compact grey limestone	0	10
Dark slaty marl, which rests on the light bluish green beds belonging to the upper part of the new red sandstone system	7	0
Total...	18	10

Lias in North Britain.

Mr. Murchison's *Memoirs on the Oolitic Deposits of North Britain*, most clearly prove the existence of well-characterised lias shales, much like those of the Yorkshire coast, in Pabba, Skye, and other of the Western Isles, and the organic remains which he collected there are of the usual English types. Lias occurs also on the North-East coast of Ireland, as at the Giant's Causeway, with ammonites and belemnites.

The lias in South Wales is a singular extension of the formation among the dislocations of the older carboniferous system, nearly analogous to its appearance among the sandstones and slates of Scotland. The Valley of the Ely, in South Glamorganshire, exhibits several upfillings of lias, commencing about five miles West of Landaff, whence, with some interruptions, they accompany the Ely to its junction with the Channel near Penarth Point. It again appears in Barry Island, and continues to skirt the coast in a Westerly direction nearly to the mouth of the Ogmore river, forming a range of bold cliffs, among which is the little harbour of Aberthaw, celebrated for the lime which it exports. (Conybeare, *Geology of England*.)

Lias in France and Germany.

We may now turn our attention to the general types of lias presented in the North and South-East of France, and in various parts of Germany.

As in England, so generally in these Countries, the lias is deposited conformably to the saliferous system, but in Brittany and around the plateau of primary rocks in central France, especially about Autun, the oolitic system often touches the granitic series without any interposition of red sandstones. In the district which borders that plateau on the East, between Chalons and Autun, the oolitic rocks are considerably developed with lias at the bottom, and all based upon gypseous red marl; but the lias clays are here almost wholly deficient, and the formation consists only of the gryphitic limestone, with its partings of clay. The abundance of gryphæa incurva, and other characters of the stone, strongly remind the traveller of the analogous beds in Lincolnshire. The lias and oolites are so closely allied that Desnoyers, in his description of this tract, hesitates even to distinguish the former as a fourth stage of the calcareous or oolitic system.

South of the Ardennes mountains by Luxemburg, Metz, and Nancy, the lias exhibits more developed characters. Immediately upon the Keuper marls rests a considerable bed of sandstone, white, yellow, or rarely brown, sometimes solid, and sometimes friable; gradually passing into the lias beds above. From its

abundance under and around the fortress of Luxemburg, it receives in that Country the name of *grès de Luxemburg*.

The proper gryphitic lias limestones succeed and cap most of the plateaux of grit. The beds are bluish and compact, and alternate with grey friable marls.

Above are grey marls and marly grits, which correspond to the lias clays and marlstone of England; and these are followed by the ferruginous sandstones which form the general floor of the oolitic system.

In Würtemberg, and, perhaps, generally on the German side of the Rhine, the lias has more of the character of the English series both as to mineralogical composition and organic remains. In particular, the saurian reliquiæ, so abundant in the lias clays of England, are all found in those of Boll and other parts of Würtemberg, and with some additional species have been described by M. Jäger, of Stuttgart. Fine specimens of saurian animals occur in many of the museums along the Rhine. But, perhaps, the most remarkable accordance between the series of Germany and that of England, is observed at Banz near Coburg, where the Maine crosses the Northern extremity of the Franconian range of oolites. Here Mr. Murchison has observed the following section.

Sandstone cap of the lias	300 feet thick.
Upper lias shale of Yorkshire	40
Marls and marlstones	150
Lower lias shale, with compact lias and ammonites Hawkerensis, near the top	300
Gryphite limestone	
Gritstone	
Keuper formation	

At this place the most astonishing profusion of saurians, fishes, crustacea, ammonites, nautili, and belemnites, as well as pentacrini, gryphites, and other fossils, occur, and many of them remarkably agree as to their place in the strata with the arrangement of the same species in the beds of the coast of Yorkshire.

Lias shales occur below the Alpine or Jura limestone of Swisserland and Savoy, and occasionally, as at Meyringen, Bex, the Mont Joux, produce some of the characteristic ammonites and belemnites of the English lias. In the Valley of the Arve, in particular, the argillaceous beds of lias are immensely thick, and owing to the igneous agency, once so powerfully excited beneath the Alps, have a schistose character strongly assimilating them to the primary slates. Whether the slates of the Valorsine belong to the same era is, perhaps, not yet ascertained; but if this should be proved, the vegetable remains which they contain, being identical with those of the carboniferous epoch, would indicate that these regions enjoyed a particular immunity from the causes which, in all other instances yet examined, had wholly destroyed the plants which grew in the carboniferous epoch, and covered the earth with cycadeæ and other entirely new types of vegetable life.

Lower Oolite Formation.

The uninterrupted range of this formation through Dorset, Somerset, Gloucestershire, Oxon, Northamptonshire, Rutland, and Lincoln, to the banks of the Humber, may be seen on the Maps of Mr. Smith or Mr. Greenough. Beyond the Humber it is concealed for a short distance beneath the overlying chalk, but emerges again, and occupies a vast breadth in the Eastern part of Yorkshire. In Sutherland, and in some of the Hebrides, and particularly in Skye, it has been traced by Mr. Murchison.

It occupies, through all its course in England, an elevated range of hills with bold escarpments to the West or North-West, a gentle slope to the East or South-East, and deep valleys of denudation which often, by descending to the lias clays, furnish most complete information as to the relations of the two formations. The surface of the calcareous portions is dry and bare of trees, and wells sunk therein often reach a very considerable depth, while upon the alternating clays the soil is cold or wet, and, in general, much covered by woods. The fertility of the district is below the average of the secondary strata. The highest point of the range in the South of England is Cleeve Pipard Hill, near Cheltenham, 1134 feet above the sea, and in the North of England, Botton Head, near Ingleby in Yorkshire, 1485 feet; but in these cases about two-thirds of the height consists of the lias clays.

The more ordinary altitudes of the oolitic range in England are 700, 800, and 900 feet, varying according to the Westward extension of the hill, the thickness of the base of lias, and the pile of incumbent strata.

Escarpments of oolite.

Certainly, this regular and continuous range of oolites, with so nearly uniform an elevation of escarpment, is one of the most characteristic features of English Geology, and furnishes matter for profound reflection. For like the parallel, equally continuous and regular, and but slightly lower range of chalk, its elevation seems not at all due to local disturbances, but rather appears to indicate a general intumescence of the land in the direction of these ranges. The low vales of lias, Oxford clay, and Kimmeridge clay, which intervene between the lower, middle, and superior oolite ranges, have undoubtedly been caused, at least in part, by the erosive action of water; but to whatever extent we apply this principle in explaining the present inequality of the earth's surface, and whatever aid we receive for the established data of local elevation, these limited agencies always leave unexplained the general fact, *viz.*, the regular altitude of continuous ranges of hills with uniformly declining planes, and no particular marks of convulsion, which overlook extensive undisturbed plains of older strata.

The vicinity of Bath, where Mr. Smith began his important researches, furnishes the general type of the lower oolite formation; and, with some modifications, the series of strata here presented, as detailed by Mr. Smith and Mr. Lonsdale, is found to be almost universally reconcilable with the phenomena of the other oolitic districts. The variations observed are principally caused by the interpolations of a larger proportion of arenaceous, argillaceous, and carbonaceous beds, so as in extreme cases to change the calcareous section of Bath into a coal field, with subordinate beds of limestone. Such is especially the case in the Eastern moorlands of Yorkshire, at Brora in the Hebrides, and in the gorge of the Weser at Minden, as observed by Mr. Murchison.

The table of classification given above, will make known the order of succession of groups recognised in this formation, and we shall now proceed to point out their characters and notice their variations more exactly.

Inferior oolite group.

The Sand which is the base of the inferior oolite group in the vicinity of Bath, possesses, in general, only a slight degree of cohesiveness, but in places passes into a friable sandstone. It is micaceous, of a yellow colour, and contains irregular courses of calcareous concretions

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called sand burrs. These nodules are often aggregated round ammonites and other organic bodies. The thickness of this bed sometimes amounts to 70 feet.

The inferior oolite varies in thickness, in some places being 60 feet, in others considerably less. The rock, according to Lonsdale, admits of being characterised in three portions, the lower one 6 feet, hard, of a brown colour, abounds in casts of trigoniæ, limæ, trochi, &c., and is seen in many sections reposing immediately on the sand. The coated muscles, as they are termed, are found in this bed, and the bed which in the descending quarries yields so immense an abundance of species is apparently of the same date. The middle division, 10 feet, is a rubbly stone; principally consisting of crystallized carbonate of lime, through which the organization of astreæ may be clearly traced. It is, therefore, a coral bed, and as might be supposed is of irregular occurrence.

The upper portion of the rock, 40 to 50 feet at the utmost, contains the workable freestone or oolite of this rock, the upper part, in particular, cannot be distinguished in specimens from the great oolite above. The lower beds are more sandy, browner, and less oolitic.

The fuller's earth group.

The fuller's earth group, so named from the occurrence in it of limited beds of that substance, is a thick argillaceous deposit with a few layers of nodular limestone and indurated marl, occurring on the hill sides of Bath, and distinctly separating the inferior from the great oolite. The following is Mr. Lonsdale's summary of these beds.

	Feet.
4. Blue and yellow clay with nodules of indurated marl	30 to 40
3. Bad fuller's earth	3 to 5
2. Good fuller's earth, brown or blue	2½ to 3
1. Clay containing beds of bad fuller's earth and layers of nodular limestone (fuller's earth rock) and indurated marl	100

The great oolite rock.

The great oolite rock contains, besides the more perfectly oolitic parts, which hold few shells and furnish the best freestone, a great number of beds, in which the oolitic structure is less evident or even wanting, and which are more or less filled with remains of shells, corallines, &c. These coarser portions of the rock lie at the top and bottom, and enclose the purer oolite between them.

The lower rags consist of several beds of coarse shelly limestones 10 to 40 feet; the lowest bed of it which rests on the fuller's earth group is fine-grained and scarcely oolitic.

The oolitic beds in the middle are very variable in thickness and quality. On Combe Down the thickness sometimes amounts to 30 feet. The stone when taken from the quarry is quite soft, and holds so much water as to be beaten to a pulp by the hammer. After being thoroughly dried it will absorb more than one-seventh of its weight of water, but by long exposure it grows harder and less absorbent. It will not stand the sea air, though in the neighbourhood of the quarries it is very durable.

The upper rags, 20 to 55 feet, consist of alternating beds of coarse shelly limestones, tolerably fine oolite sand, tough, brown, argillaceous limestone. The shelly beds were used by the Romans in their buildings at Bath, and are thought to be very durable, but are difficult to work. Some of these beds are full of millepores and other polyparia and species of echini, and a profusion of minute univalve and bivalve shells. They often exhibit that peculiarity of internal lamination called false bedding, when the ingredients of the stone form layers inclined to the plane of stratification.

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The forest marble group.

The forest marble group admits of the following subdivision in a descending order:

	Feet.
6. Clay with occasional laminæ of grit. And at Norton St. Philip a layer of rubbly indurated marl abounds with fragments of a small oyster and terebratula.	15
5. Sand and nodules, or beds of calcareous gritstone. The sand is reddish-yellow or white, pure or mixed with clay, or lime. The gritstone, usually of a brown but sometimes of a blue colour, exists in spheroidal masses which have a laminated structure parallel to the stratification, and occasionally can be split into flags. The fracture often shows shining facets of interposed carbonate of lime. Organic remains are generally rare in these beds, sometimes particularly abundant.	40
4. Clay with thin slabs of stone and laminæ of grit	10
3. Coarse oolite, or shelly limestone (forest marble) full of fragments of wood and shells, especially ostreæ and plagiostomata, bones, teeth, &c. The majority of the beds have a fissile structure, and can often be split into thin flags, or tiles, oblique to the plane of stratification. Thin partings of clay generally divide the beds.	
2. Sand, or sandy clay and grit	10
1. Pale blue or grey clay, enclosing thin slabs of tough brownish limestone and laminæ of calcareous sandstone or grit. Thickness variable	5 to 40

The cornbrash.

The cornbrash consists of numerous rubbly beds of coarse limestone, mixed with clay, altogether 10 to 15 feet thick. The beds or rather nodules are extremely irregular, and of different colours, but they are pretty uniformly composed of tough granular limestone, and abound with terebratulæ, avicula echinata, isocardia, amphidesmata, &c.

In tracing the lower oolite formation to the South from the Bath district, the inferior oolite is found to become more ferruginous, (Sherborne,) and with its subjacent sand to cap the lias as far as Bridport, but the great oolite soon "thins out," while the forest marble group thickens and becomes predominant. The cornbrash retains its usual characters and fossils.

In the district lying North of the Humber the lower oolitic system assumes entirely new characters which will require separate consideration. The beds seen in the imperfect exhibition of these oolites near Cave, where they divide the lias from the Oxford clay, are, the sand of the inferior oolite covered by shelly and oolitic beds, a continuation of the oolite of Lincolnshire, and above them a thin bed of pale blue clay. They are here much diminished in thickness, and, though burnt to lime, somewhat debased in purity. On the banks of the Derwent, the lias is surmounted by the same simple series, with the addition of beds of calcareous flagstone above. Further along the range, at Brandsby and Wiganthorpe, the series is expanded by the interposition of beds of sandstone and shale, with a thin band of coal between the sand which caps the lias, and the shelly limestone which here represents the oolite of Lincolnshire. Above the limestone runs a band of pale blue clay; and upon this rests a succession of beds of sand and sandstone, enclosing spheroidal concretions of calcareous sandstone with glistening facets, often blue in the centre and full of shells, some of which resemble those of Stonesfield. Beds of sandstone, shale, and carbonaceous matter are also interpolated above this slaty rock. The oolite here is hardly deserving of

Lower oolites of Yorkshire.

that name from its lithological character, for though this appearance sometimes presents itself, the greater part of the stone is a coarse, granular, shelly limestone, with imbedded shells, &c. It is, in fact, the oolite of Cave still more degenerated. The series of sandstones and shales with coal which here overlies the sandstone cap of the lias, has been supposed analogous in position to the fuller's earth group of Bath, (the similar series which overlies the limestone beds corresponds to the interval between great oolite and cornbrash,) and as we proceed Northwards both series increase immensely in thickness, so that the lower one reaches 500 feet, and the upper one 200; and as, from local circumstances, the coal, though never more than 16 inches thick, is worth working, these moorlands assume the appearance of a true coal field, with subordinate beds of very coarse shelly limestone. It requires, indeed, very close observation to trace the thin limestone beds across these vast moors, and amidst such a number of sandstone beds. They are best studied on the coast. The sandstone upon the lias is here a variable rock often coarse and fragmentary, sometimes with the characters of ordinary sandstone, but generally subcalcareous, ochraceous, and full of shells and casts. At Blue Wick, near Robin Hood's Bay, it presents a double band of fossil-bearing beds, the lower one gradually passing to the subjacent lias. The limestone appears with different aspects at different points. Under Gristhorp cliffs it recalls pretty exactly the oolite of Cave, but at Scarborough, Cloughton, Hawsker, Sneaton, &c., it is a very different rock, coarse, fragmentary, and mixed with veins of earthy and argillaceous oolite, so as to be scarcely fit to be burned to lime. In the Staintondale cliffs it is a double band; at Whitenab it is covered by calcareous sandstone slate, in which glistening facets, like those in the stone of Brandsby and Wittering, occur. Only one seam of coal is worked in the district, and it lies beneath the limestone. The cornbrash appears on the coast, also, in a debased but recognisable form. The fossil plants which accompany the coal seams and sandstones, may also be detected in the limestones and calcareous slates both on the coast and at Brandsby; and it is worthy of particular attention, that both at Collyweston and at Stonesfield, several of these plants occur in the slate, as brachyphylla, ferns, and cycadites. No marine exuviæ have yet been found in these coal grits or shales, but some bivalves resembling anodon, which perhaps were swept down with the ferns, equiseta and cycadeæ, are found at Gristhorp. In several places, a particular part of the section of lower carboniferous sandstones, exhibits the remarkable phenomenon of equiseta standing irregularly erect over considerable areas in a bed of sandstone which rests upon shale.

This is, therefore, truly a coal field of the oolitic era, produced by the interposition of vast quantities of sedimentary deposits brought down by floods from the land, between the more exclusively marine strata of the ordinary oolitic type. We may believe this to be a case of a littoral deposit of oolite, and should naturally derive from that supposition, the debasement of quality and attenuation of thickness of the shelly limestones, in proportion as the spoils of the land brought down into the sea were more abundant. Whatever the causes were which produced these effects, they were not entirely local. The Yorkshire oolitic district is indeed the only tract yet investigated in England which exhibits these effects in a striking manner; but attentive consideration of the phenomena presented by the rag beds of oolite and coarse shelly beds of forest marble near Bath, and still more the wavy surface and vegetable fossils of some kinds of the sandstone slate of Ridge, Stonesfield, and Collyweston, will lead to the conclusion that these portions of the oolitic formation were deposited within the influence of the littoral agitation of the sea. (Mr. Scrope has presented a notice of this subject to the Geological Society.)

Another fact is important. The extensive additions of terrestrial plants and sediment are confined to the intervals between the sand which is the base, and the cornbrash which is the cap of the lower oolite formation.

Mr. Murchison's examination of Brora and other points in Sutherland, and of the Western coast of Scotland, has proved the extension of the carboniferous system of the Yorkshire oolites into these Northern regions, and it is interesting to observe that there, as well as in Yorkshire, the interpolations occupy the same limited space in the section.

The following short summary of the beds in these Countries will prove this point:—

Section of Brora.

Middle oolite formation consisting of	Calcareous grit and Oxford clay.
Lower oolite formation consisting of	Shelly limestones representing cornbrash and forest marble.
	Alternations of sandstones, shales, and ironstones with plants.
	Ferruginous limestones, blue in the interior, with fragments of carbonized wood and abundance of shells.
	Sandstones and shales of great thickness in frequent alternations with plants, having *in the upper part* two beds of coal, of which the upper one is 3 ft. 8 in. thick, the lower one, not worked, 1 ft. 4 in.

Lias formation with fossils of the Yorkshire lias.

North-East Coast, Isle of Skye.

Sandstone series.
Shelly limestone.
Sandstones and shales of great thickness, with obscure impressions of plants and abundance of carbonaceous matter.
Calciferous sandstone beds, with small nodules of indurated limestone grit, with fossils and thin layers of shale with belemnites.
Blue shale (upper lias shale of the Yorkshire coast) with small blue calcareous concretions, belemnites, &c.
Sandstone with concretionary nodules and fossils of the marlstone series.
Lias shale.—*Geological Transactions, New Series.*

The same Geologist has found a considerable analogy to these phenomena in the section presented by the gorge of the Weser, where that river escapes through the Porta Westphalica into the plains of Northern Germany. How unlike to the general type of the oolitic formation of the German and Swiss Jura!

Having thus produced the two most contrasted types yet discovered of the lower oolite formation, and by their comparison put a severe check upon the doctrine of universal formations (if such was ever entertained) among the secondary strata, it will be useful to state the leading features of this formation in the intermediate parts of its range in England, and thus to ascertain the parts which vary, and the method of their variation. To do this with entire satisfaction is not easy, and indeed requires more data, yet the curious fact of the

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continuity of the cornbrash above, and of the lower oolite sand below, from one end of England to the other, by furnishing every where exact limits to the formation, very much abridges the inquiry and diminishes the chances of error. In the long range from the coast of Dorsetshire to the coast of Whitby, the character of the lower sand varies, yet not so much as is common to sandstones, the principal difference consisting in the colour which is occasioned by the degree of oxidation of the iron. Through Oxfordshire, Rutland, Lincoln, and the Southern part of Yorkshire, it is a very dark brown ferruginous rock, whence it is often called "gingerbread stone," frequently enclosing shelly concretions, (Banbury,) occasionally enveloping beds of limestone, and sometimes (Northampton, Rockingham) interlaminated by white beds of oolite. The quantity of oxide of iron is sometimes so considerable as to divide the mass of the rock into a multitude of ochraceous cells or "iron boxes." In some places, especially in Lincolnshire, it consists of an alternating series of white and brown sand.

With respect to the cornbrash it is sufficient to say, that though so unimportant a rock in other respects, it is probably more continuous, and more uniform in its character from Dorsetshire to the Humber, as may be seen in Mr. Smith's Maps, than any other member of the lower oolitic formation except the sand of the inferior oolite.

Lincolnshire.

Lincolnshire presents the following section of this formation: (observations made in 1821:)

Cornbrash full of its usual fossils.
Clay thin.
Thin shelly beds *in one locality*, somewhat resembling the blue beds of Farley near Bath.
A considerable thickness of clay ground, presumed by Mr. Smith to include the forest marble system of Wiltshire.
Sandy laminated stone, in a few localities South of Lincoln.
Thick, apparently undivided, oolitic rock, very productive of organic remains, with polypiferous beds on the top.
In the upper parts of this rock, false bedding is frequent, coarse shelly rags abound, good oolite is dug at Ancaster. This is undoubtedly the same rock as that of Cave in Yorkshire, and it is continuous with the same general character as far as Grantham, between which place and Stamford there appears to be some change.
Inferior oolite sand.

Between Stamford and Peterborough the series was recorded thus: (1821:)

Cornbrash	Rag beds of Barnack.
Clay of some thickness.	Stamford oolites, and
Sandy laminated beds at Pilsgate.	Inferior oolite sand.
Interval not known.	

On the line from Wandsford, through Weldon to Rockingham: (1821:)

Cornbrash very distinct.
Clay of some thickness, nothing else observed.
Weldon oolite or rag, the same as the Barnack rag.
Interval, presumed to be clay, under some breadth of Rockingham forest
Brown sand of Rockingham Hill, with interlaminated white limestones.

It might appear from these statements that the slates of Wittering and Collyweston are near the Northern end of these deposits; they are unknown at present in a distinct form North of the Welland, except at Market Deeping, though probably represented by the sandy cap of the Lincolnshire oolites.

Collyweston slate.

The slate of Collyweston is associated with beds of oolite and compact limestone, and presented to Mr Murchison and the author the following detailed section.

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Local Names.	Ft. In.	Description.
Rubble........	4 0	Imperfectly bedded oolite.
Cale	4 0	Irregular and broken beds of oolite.
Bedding sand ..	1 3	Fine yellow sand indurated at top and at bottom into concretionary and slaty layers.
Broad	4 0	Brown hard oolite graduating upwards to the sandy layers above. Thin beds, not burnt to lime.
Limestone	1 6	Hard, compact, not oolitic, containing brachyphyllum, ferns, and trigonellites.
Belch.........	1 3	Irregular sandstone.
Slate......2 to	4 0	Masses irregularly spheroidal flattened, very fissile, in general calcareous grit not at all oolitic, but shelly, with littoral and terrestrial plants.
Fine sand		Of a yellowish colour.

The slate is quarried only in Winter, for if dried by the Summer Sun and wind, it hardens and will not split. The holes are blocked up in Spring, and the quarrymen only employed in preparation of slate. It is, in general, very equally laminated. The splitting is caused by organic exuviæ.

Stonesfield slates.

The Stonesfield slates near Oxford have been almost universally esteemed of the same age as these Collyweston rocks.

At Stonesfield two beds of concretionary masses, capable of being easily (with the assistance of frost) split into slate parallel to the stratification, compose with sand and friable sandstones a group 5 or 6 feet thick, under 50 feet of alternations of laminated shelly oolite and thin blue clay. The following is Dr. Fitton's account of the section. (*Zool. Journal*, vol. iii.)

Rubbly limestone.	32 feet.
Clay with terebratulites.	
Limestone.	
Blue clay.	
Oolite.	
Blue clay.	

"Rag," consisting of shelly oolite, with casts of bivalves and univalves.

The slate beds consisting of	"Soft stuff," 6 in. yellowish-sandy clay with thin courses of fibrous transparent gypsum. "Upper Head," 1 ft. 3 in. to 1 ft. 6 in. sand enveloping a course of spheroidal laminated calcareous grit stones which produce the slate. These are called "Potlids" from their figure, and receive with the other slaty bed the name of Pendle, as characteristic of the workable stone. The stone is partially oolitic and shelly, sometimes full of small fragmentary masses. "Manure or Race," 1 ft. slaty friable grit rock.
The slate beds consisting of	Lower Head 1 ft. 6 in. to 2 ft. sand and grit, including a course of spheroidal concretions of slate like that described above. Bottom stuff, 1 ft. sandy and calcareous grit with admixture of oolitic grains.

The floor of the slate beds is rag like the oolite above.

Most of the Stonesfield fossils, and in particular the jaws of didelphidæ, have been extracted from one or other of the courses of slate.

We may now return to the Bath series of oolites, and accompany Mr. Lonsdale in his recent survey of their extension to the Northward.

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Lower oolites of Gloucestershire.

The *inferior oolite* in the South of Gloucestershire consists of nearly equal divisions of soft oolite and slightly calcareous sand; but in the Northern division of the County the latter, for the greatest part, is replaced by a yellow sandy limestone. The freestone beds, which are not to be lithologically distinguished from those of the great oolite, gradually increase in number and thickness from the neighbourhood of Bath to the Cotteswold, East of Cheltenham, where they constitute the whole of the escarpment. This vertical importance is retained through the North of the country examined; but to the Eastward of the valley, ranging from Stow on the Wold to Barrington, near Burford, a change takes place both in the structure and thickness of the formation. The freestone beds are there replaced by strata of nodular coarse oolite, containing numerous impressions of *clypeus sinuatus*, the sandy portion consists of only a thin bed, and the thickness of the whole of the inferior oolite group is diminished from 150 to about 50 feet.

The *fuller's earth* loses its importance in proceeding Northward, yet it was traced as a parting between the great oolite and the inferior oolite, as far as a line passing from the neighbourhood of Winchcomb to Burford, but to the North-East of this line it thins out.

Great oolite. The threefold arrangement of upper rags, fine freestone, and lower rags, into which this rock is naturally divided near Bath, does not prevail uniformly in our progress Northward.

The upper rags, consisting of soft freestone and hard shelly oolite, were traced to Cirencester; but to the North-East of that town they are replaced by a rubbly, white, argillaceous limestone. The beds of the middle division become chiefly a hard oolitic limestone. At Wotton under Edge the lower rags are replaced by beds of fissile, calcareous sandstone, which runs through the whole of Gloucestershire to the neighbourhood of Burford. They are extensively worked as a tile stone, possess the lithological character of the Stonesfield slate, have their fissile property in the same way developed by exposure to atmospheric agency; contain *trigonia impressa*, the characteristic fossil of Stonesfield; and on comparing the strata of Burford with those which rest at Stonesfield on the slaty beds, it was found that an almost perfect identity of character and order of position prevailed at the two localities. The Windrush quarries near Burford give the following section for comparison with that of Stonesfield previously detailed.

Top.	Rubbly limestone	1 foot.
	Brownish marlstone	6
	Rubbly limestone...............	4
	Pale sandy marl.....	3
	Rubbly limestone	½
	Light-coloured clay	½
	Rag and freestone	15
	Sandy laminated grit............	—

Mr. Lonsdale has thus corrected the almost universal error of English Geologists in classing the Stonesfield slate with the forest marble, and has assigned its true place at the base of the great oolite; a most important alteration in every point of view.

The forest marble was found to possess the same characters as near Bath, consisting of a thick stratum of laminated shelly oolite, interposed between beds of sandy clay, containing laminæ of grit; and to have, from Bath to near Fairford, for its uppermost stratum, a deposit of loose sand, containing large masses of calcareous grit.

It is hardly to be doubted that the slate of Collyweston is coeval with that of Stonesfield, but it must be left to further investigation to decide whether the thick oolites of Lincolnshire comprise both the great and inferior oolite of Bath, or which of them exists there alone. It is now ascertained that there are calcareous slaty beds in two points of the series between the cornbrash and the inferior oolite; it is known that both the great oolite and inferior oolite are subject to great variation of lithological character and thickness, and that the fuller's earth which distinguishes these rocks at Bath is extinct, or nearly so, North of Burford. The problem, therefore, now presented to Geologists by the yet unfinished survey of the oolites, is rather complicated, and demands much labour to perform with full effect. It should be begun by taking up the subject where Mr. Lonsdale's observations end, *viz.* at Burford, and the ground examined minutely Northwards. We may venture to promise that this will not be wholly neglected.

Middle Oolite Formation.

General description.

Very strong analogies accompany all the leading divisions of the oolitic system, and mark them as the products of a succession of similar causes. As the oolites of Bath lie enclosed between strata of calcareous sand, so those of the middle division are imbedded between strata of calcareous sand and sandstone, and the association of the upper oolite with green sands at Swindon and Thame, is probably of the same intimate description. The organic fossils of all the divisions have a striking general resemblance, and the composition of the rocks is liable to similar variations.

The physical features impressed on the geography of the country which they traverse are also very similar. As the consolidated strata of the lower oolite formation form a high escarpment, which overlooks the plains of argillaceous lias; so the limestones and sandstones of this middle group rest on a bold edge, above the vales of Oxford clay, and the upper oolite rocks in the few places where they occur domineer in the same manner over the vales of Kimmeridge clay. It might have been attended with some convenience to have considered these thick clays in formations apart from the rocks, as the lias has been separated from the lower oolite, but they are from various causes so connected with them that it would have injured the practical utility of the classification.

The general characters of the surface of the middle oolite formation, are a moist valley of Oxford clay below a dry range of hills, furnishing copious springs from the calcareous grits and oolite. Dry valleys, deep wells, narrow dells, washed by the rapid streams, occur, especially in the districts of greatest altitude, and one unacquainted with the series of formations might recognise in the general aspect of *this*, the description usually given of the lower oolite range. Outlines of the oolites and sandstones occasionally cover insulated hills of the subjacent clay, and prove the denudating power of ancient floods. The altitude of this range of oolite nowhere equals that of the lower oolite in the same region. Thus while in Yorkshire the rocks rise in Botton Head to 1485 feet above the sea, the former reach on Black Hambleton 1240 feet. In Oxfordshire

and Gloucestershire 800 or 900 feet is the height of the lower oolite, but 400 or 500 feet that of the middle oolite.

Range and extent.

This formation is upon the whole less continuous than the one described before, yet the discontinuity is not of the whole mass, but chiefly of the group of oolites and sandstones. These have a considerable developement in Dorsetshire; first on the coast at Weymouth, and secondly from near Sturminster to beyond Wincanton, where they produce oolitic freestone. Hence to Longleat Park they are unknown. From Longleat their range is unbroken by Westbury, Calne, Wootton Basset, Highworth, Farringdon, and Abingdon, to the banks of the Thames at Oxford. They can be traced under Shotover, and towards Brill, a few miles, but their further course is unknown, till we arrive under the Wolds of Yorkshire near Acklam. At this point emerging from beneath the chalk, they encircle the Vale of Pickering by Malton, Helmsley, Pickering, and Scarborough, increase greatly in importance, and assume more completely than in any other part of England, excepting perhaps Weymouth, the full characters of their formation. But while the oolitic group is thus dismembered into four widely detached regions, the Oxford clay beneath is as remarkably connected from the North side of the Dorsetshire downs, by Wincanton, Melksham, the Vale of the Isis, Ottmoor, the Vale of Bedford, Huntingdon, the Western border of the Fens, and the Vale between the Cliff and Wold ranges of Lincolnshire to the banks of the Humber. Beyond the unconformity of the chalk wolds, its course is undivided beneath the slope of the calcareous grit round the Vale of Pickering to Scarborough.

We shall now offer a few details of the internal structure and variations of these rocks.

The *clay* below the Kelloway rock has been very little noticed, and is indeed not very important. It occasionally contains pholadomyæ and other shells near Bath, and more frequently abundance of selenite, and on the coast of Yorkshire has yielded some curious remains of crustacea. As for the greater part of the range of the Oxford clay the Kelloway rock is unknown, this clay can seldom be distinguished. In Yorkshire it barely reaches a few yards, and generally is less than three feet in thickness.

Kelloway rock.

The Kelloway rock, so named by Mr. Smith from Kelloway Bridge in Wiltshire, which is almost the only place where it occurs in the South of England, is in that County more remarkable for the beauty, peculiarity, and abundance of ammonites, gryphææ, and other organic remains which it produces, than for either its thickness or continuity. It is there a calcareous sandstone, appearing when devoid of organic remains very similar to those which accompany the coralline oolite, externally brown, internally grey or blue, of a rubbly nodular structure, altogether less than twelve feet thick. From Wiltshire to Northamptonshire no mention is made of this rock, but it was found with its usual fossils at Boziate Hill, near Wellingborough, by the writer of this Article, in company with Mr. Smith in 1820.

In 1821, the same observers established the occurrence of the Kelloway rock at Hackness and Scarborough on the sea-coast of Yorkshire. It is coextensive in that County with the range of the Oxford clay, from under which it rises into an escarpment. It arrives sometimes at a thickness of sixty feet, and is then locally distinguishable into several portions. It is, however, altogether a mass of sand and calcareous sandstone, with or without organic remains; the upper beds very thick, indurated by admixture of oxide of iron, and multitudes of gryphææ, belemnites, ammonites, and avicula, and other fossils. Not unfrequently in the vicinity of the shells it becomes sufficiently calcareous to assume the character of a sandy oolite, sometimes ferruginous like that of Dundry. The sandy parts of the mass are often variously stained brown, reddish, yellow, or remain perfectly white, in layers or irregular stripes, and traversed by dissepiments of oxide of iron. In a very few places it is useful as a building stone.

There is perhaps no more curious fact on record than the occurrence of this apparently indefinite rock, with almost identical characters, after so great an interruption of continuity.

Oxford clay.

The Oxford clay (clunch clay of Smith) appears, in the whole of its range South of the Humber, a pale blue clay, turning yellow on the surface, with large sparry septaria, and some layers of chocolate-coloured shale, (Tytherton,) with ammonites and other fossils. In Yorkshire, it is less tough, and more generally laminated, gradually changing in quality to the Kelloway rock below, and the calcareous grit above. Most of the organic remains which it yields belong to the lower part of the stratum, and are in general identical with or very similar to those of the Kelloway rock. Taken in general terms, the suite of fossils at Weymouth belonging to the Oxford clay is considerably allied to that of the Kelloway rock and Oxford clay of Yorkshire, but further comparison of the species of ammonites is yet needed. In the Museum at Strasburg fossils of the Kelloway rock, as well as of the Oxford clay, are recognised.

It is painful to observe the dreadful waste of money in ill-advised trials for coal along the line of the Oxford clay. The least fragment of jet or morsel of bituminous shale, especially if accompanied by "blue metal," is enough to make a credulous proprietor listen to an ignorant collier, and throw away the value of his solid land in sinking for the imaginary treasures beneath it.

Coralline oolite group. Lower calc grit, Wilts, &c.

The *lower calcareous grit* should be carefully distinguished from the iron sand, with which Mr. Smith has occasionally confounded it, nor is the distinction difficult, for, independent of its geological position, the calcareous grit is not particularly ochraceous, and never assumes that dark ferruginous aspect so remarkable in the other rock. In Wiltshire, where it was first observed, it appears as a thick stratum of sand, inclosing irregular beds of sandstone, or of calcareous grit, which assumes the aspect of coarse limestone. These sandstones are brown externally, but grey or blue within. Irregular layers of clay occur in places, and friable beds of decomposed shells. The prevailing colour of the sand is yellow, but sometimes it is ash-coloured. At Studley, near Oxford, Dr. Buckland detected a peculiar bed of clouded grey colour, and very tough and dense texture, a sort of argillaceous chert, rich in pinnæ, ammonites, and other organic remains. It probably belongs to the lower part of the rock.

The calcareous grit of Heddington, also rich in organic remains, ammonites, belemnites, plagiostomata, pectines, &c., is a very coarse rock, with an abundant admixture of quartz pebbles, chiefly of small size, and fragments of shells. It forms irregular beds and concretions in beds of quartzose sand, mixed with calcareous matter.

Professor Sedgwick's description of the calcareous grit of Weymouth makes us acquainted with a more complete series than that of Wiltshire and Oxfordshire. The following statement of beds there is in the ascending order:

a. The lowest beds upon the Oxford clay are black, and meagre to the touch, filled with irregular branching stems like alcyonia.
b. Thin beds of yellow sand and sandstone.
c. Strong ferruginous jointed beds of calcareous grit.
d. Blue argillaceous beds, alternating with hard compact beds with an even fracture.
e. Yellow sand like b, with beds of calcareous grit in the upper part.
Beds of oolite succeed.

The section of the lower calcareous grit on the Yorkshire coast between Filey and Scarborough has a striking resemblance to that of Weymouth. Immediately on the Oxford clay rests a series of grey marly sandstones, 70 feet thick, gradually becoming more yellow and more consolidated upwards, till they assume the harshness which belongs to stones usually called cherty. This cherty bed appears to correspond with that mentioned before at Studley. It continues across the moors to Hambleton. Above these runs a band of yellow sand, nine feet thick, enclosing large spheroidal highly indurated calcareous balls. This band is traceable through the interior, where it forms rabbit-warrens, as far as Whitestone Cliff, and there the balls are of immense size. When they fall out, the rock looks cavernous. The upper part of the rock consists of strong beds of calcareous sandstone, very remarkably covered on the surface, and also penetrated by branching cylindrical bodies, which continually remind us of sponges. The upper beds of this series are of a redder colour, and more calcareous than the others, remarkably full of shells, and in some places alternate with two or three beds of oolitic limestone also shelly. In the interior of the moors, they are often used for wallstone. It is not always quite easy to draw the line between them and the oolite above, especially when the latter is unusually shelly, and no coral bed intervenes.

According to Mr. Lonsdale there is in Wiltshire a pale blue clay, 10 feet thick, interposed between the lower calcareous grit and the coralline oolite.

The coralline oolite, or coral rag group, as described by Smith, Conybeare, and Lonsdale, near Oxford, Wootton Basset, and Bath, seems not so complete a series as that described by Professor Sedgwick at Weymouth, and by other authors in Yorkshire.

Weymouth. The thickness of the whole group is greater in Yorkshire than elsewhere, but no where in that country exceeds 80 feet. The section at Weymouth gives above the calcareous grit the four following groups:

Many beds of pure oolite with beds of argillaceous partings, alternating with other shelly oolitic beds, somewhat resembling forest marble. In some of these beds the oolitic particles are associated with a variety of marl, and are incoherent.
Thin beds of oolitic marl, containing innumerable specimens of the small clypeus clunicularis, casts of melaniæ, &c.
Beds of impure sandy oolite, containing, besides other fossils, a few specimens of ostrea deltoidea.
Thick limestone series, at the bottom of which lie masses of coral rag, containing caryophyllia annulata, astrææ, &c. with innumerable fragments of trigonia clavellata. In the higher portion are many meagre sandy beds, nearly resembling the lower calcareous grit, but more calcareous, and with a finer suite of organic remains.

...shire, Wilt... Mr. Lonsdale describes the Wiltshire coral rag in three divisions which do not succeed one another in any certain order, but rather intermix with and replace one another. One of them, from which the formation takes its name, is an irregular mass of nodules mostly crystallized, but sometimes earthy, and connected together by pale bluish clay. These nodules consist of little else but corals of the genera astrææ, caryophyllia, and agaricia, especially the former, which sometimes separately compose the whole mass. The lower part of this bed sometimes affords a dark blue crystalline limestone.

Another form of the rock is found in the oolite of Calne, which consists of alternations of hard shelly oolite used for flags, and soft, perishable, scarcely oolitic, limestone, workable by sawing parallel to the beds.

This form of the rock passes into the third or rubbly oolite, which is the most abundant variety in Wiltshire. This is a nodular rock with very indistinct stratification and much irregularity of texture, occasionally with ova three-tenths of an inch in diameter, constituting what is called pisolite.

In the deep pit through Kimmeridge clay on the line of the Wilts and Bucks Canal, this rock was very thin, scarcely oolitic, but chiefly a cellular mass of caryophylliæ and astrææ, and a similar character prevails in some quarries in the neighbourhood of Wootton Basset. Below it the lower calcareous grit was in the state of loose sand.

Mr. Conybeare divides the coralline oolite near Oxford into two parts, of which the upper is a calcareous freestone of close texture, full of comminuted shells, and irregularly oolitic or pisolitic.* The beds are very thick, and the stone has been much used in buildings at Oxford, but is not found to be durable. The lower part is the true coral rag, consisting of two or three courses of nodular rubbly rock, very crystalline in aspect, and composed of masses of astrææ and caryophylliæ, with admixture of echinital and shelly fragments. Oxfordshire.

In Yorkshire the lower beds of the coralline oolite are in general exceedingly shelly, and full of clypeus dimidiatus, clunicularis, &c. and on the North side of the Vale of Pickering, at Hackness, Ebberston, &c. are marked by an irregular bed of coral (astrææ) and sponges. The middle part of the rock is regularly bedded with thin partings of clay, and very large vertical joints; the different beds vary much in the same quarry, from a soft, loose, whitish oolite to a solid rock with blue centres and large pisolitic spherules. At Malton it is more uniformly oolitic, and very full of melaniæ, trigoniæ, plagiostomata, &c. and organic remains of all kinds. Near the upper part in the Ayton quarries is a bed of caryophylliæ and echini, and the rock is crowned at Sinnington, Helmsley, &c. by a bed filled to excess with turritellæ and melaniæ. Melania striata and turritellæ occur near the top of the rock about Brompton and Hackness, but at Malton they lie indiscriminately. Ammonites chiefly belong to the lower beds. About Kirkdale and Helmsley layers of obscurely defined nodules of bluish-grey chert, having the texture of sponges, lie in the lower part of the rock, and remind us of the silicious sponges of the Portland oolite. Yorkshire.

These sections will show at once the general accordance of the characters of this irregular oolite, its variable thickness, and indefinite order of succession, circumstances which belong indeed more or less to all the oolitic formations. The corals which characterise the rock, lie very unequally, yet perhaps we may perceive a tendency to form two layers, one near the top, the other at the bottom of the rock. The Oxford series seems

imperfect by the deficiency of the upper members; a circumstance probably connected with ancient denudations, by which also this rock has been greatly affected in different parts of Yorkshire.

Upper calc grit.

The upper calcareous grit, obscurely indicated at Weymouth, and very thin and unimportant in Wiltshire, (where it appears separated from the oolite by ferruginous clay,) is of considerable note along the North side of the Vale of Pickering, especially about Helmsley and Hackness. It then reaches even a thickness of 60 feet, and by intercalating its upper part with the Kimmeridge clay establishes a transition from the middle to the upper oolite formation. It is in general more ferruginous and less cherty than the lower calc grit, and in Yorkshire contains apparently fewer organic remains, but of the same kinds. It has been entirely removed by denudation from the oolite cliffs of the coast. At Weymouth its fossils are numerous and fine.

Upper Oolite Formation.

The upper or Portland oolite formation, consisting of limestone above and clay below, might be expected to occupy a country, whose physical geography should strongly resemble that of the district of coralline oolite. The area occupied by the calcareous group is indeed so very small in England, that little can be said on this point concerning it. Its commanding appearance in Portland Isle, in the Vale of Pewsey, at Swindon, and in the Vale of Aylesbury, is analogous to that of the oolitic rocks in general, and the sands with which it is in some places associated, increase this resemblance.

Kimmeridge clay.

The Kimmeridge clay in its much longer and more connected range in Dorsetshire, Wiltshire, Berkshire, and Buckinghamshire, (where it can be traced at least as far as Little Brickhill,) and beneath the wolds of Lincolnshire, and through the Vale of Pickering in Yorkshire, presents the usual characters of a thick clay deposit, broad vales with a cold, stiff soil, without springs.

The Kimmeridge clay at its typical locality in the Isle of Purbeck appears in the cliffs, as a laminated clay, bluish or greyish-yellow, dividing spontaneously like other shales into large tabular masses, the joints often lined by calcareous spar. Layers of small argillaceous nodules occur. It passes gradually into a bituminous shale, imperfectly combustible, and finally into layers of brown shaly coal, specific gravity 1.319, which burns with a smoky yellowish flame. Alum was formerly manufactured from these shales. The group is supposed to equal 600 feet in thickness. (*Geology of England*) In the Vale of White Horse at Even Swindon, it was penetrated by a well to the depth of 233 feet, and the additional thickness of the incumbent beds in Swindon Hill being taken at only 70 feet, the stratum will appear 300 feet thick. Near Oxford it is only 100, and at Bagley Wood was found only 70. In Lincolnshire and Yorkshire its thickness generally appears much less through the unconformity of the chalk strata.

Near the bottom of the Kimmeridge clay in the Vale of White Horse, below the layers of ostrea delta, were found a band of coarse oolitic ironstone with fossils and layers of septaria, with ammonites, trochi, and many other fossils much allied to those of the coralline oolite. Shale and bituminized wood were found at about the middle of the clay, and above this a course of thin balls of stone with mineral water. Near Weymouth the lower part of the clay contains, *above* large beds of ostrea delta, beds of ferruginous impure calcareous grit, partially oolitic, and alternating with beds of red and green sand and blue clay containing ostrea delta. Small bands of calcareous grit may be seen in the lower part of the Kimmeridge clay of Yorkshire, below layers of ostrea delta. It thus appears that the remarkable species of oyster so named by Mr. Sowerby is a very characteristic fossil of the lower parts of this clay group, and its manner of occurrence is equally so. For whether in Yorkshire, at Helmsley, Kirby Moorside, Elloughton, &c. in Lincolnshire at Market Rasin, at Little Brickhill in Buckinghamshire, at Heddington near Oxford, at Even Swindon and Pensey Vale in Wilts, or at Weymouth, and we may add, at Havre, it always appears in broad continuous floors, parallel to the planes of stratification, the valves usually together, with young ones occasionally adherent to them, and entirely imbedded in clay, without nodules or stones of any kind, and without any other organic remains in the layers.

Portland oolite, &c.

The upper oolite group consists, like those previously described, of a variable mass of sand and sandstone concretions, surmounted by a partially oolitic, shelly limestone. Were the rock to be seen more completely it is probable that it would also show a less definite arenaceous zone above. In Purbeck it is covered by the fresh-water or Wealden formation, and in Wiltshire, Berkshire, and Buckinghamshire by the green sand.

The varieties of composition in the limestone are such as have been noticed for the other oolites, *viz.* fine-grained white oolite, loose granular limestone of earthy aspect, and compact cretaceous limestone with conchoidal fracture.

In the Island of Portland the groups present, according to Mr. Webster, (*Geological Transactions*,) the following characters.

Upper beds ..	*Stone brash*, a cream-coloured limestone	3 feet.
	Parting of the same with black clay ...	1
	Cap stone, in three layers, with partings of clay, cream-coloured and hard, so as to turn the points of the tools.....	10
Middle beds..	*Roach*, a rock composed of fragments of oyster shells, cemented together	6
	White beds, marketable stone	5
	Layers of flint and stony rubbish......	6
	Middle bed, marketable stone, with few marine impressions	5
	Parting stone with shells of no value ..	2
	Third bed with few shells, generally the most saleable freestone	7 to 14
Lower beds ..	Many layers of flints and of unserviceable stone......................	50 to 60

Still lower, according to Dr. Buckland and Mr. De la Beche, is a bed of sand and sandstone 80 feet thick, with green grains, and very like to the lower green sand.

At Chicksgrove, in the Vale of Tisbury, Wilts, the series of limestones, more or less associated with sand, especially in the lower part, reaches more than 60 feet in thickness. Miss Benett, who has extracted so many treasures from those quarries, has given a minute section of the beds.

The five upper beds, amounting to 29 feet, consist of white limestone, locally called chalk, with one interposed layer of bad shelly stone, and a band of cherty flint 4 inches thick. The middle bed of this limestone, 2 feet thick, is excessively rich in shells, but the thicker beds above and below contain none.

The next three beds of the quarry, amounting to 10 feet, consist of sandy limestones, with fragments of shells.

Five beds below consist of sandy limestone, mostly compact and shelly, with grains of green sand in greater or less abundance.

The three lowest beds are composed of loose sandy limestone, with more or less of the green grains before noticed, shells and fragments of shells.

The shells most abundant at Chicksgrove are trigoniæ, pectines, ammonites, uniones, trochi, &c.

Brill, &c.

The imperfect sections at Brill Hill and Garsington present several points of analogy with the above section, especially in the presence of the cretaceous bed, and the quantity of sand below the calcareous part of the rock is well seen here and at Shotover, where it encloses in the lower part large, grotesque, concretionary blocks of sandstone, sometimes full of shells, and generally abundant in green grains.

Abundance of green grains accompany these lower beds in their course through the Vale of Aylesbury, and are also recognised at Swindon.

The height of the ground occupied by the detached portions of the upper oolite group is considerable in Brill Hill, (780 feet,) in Shotover amounts to 500 feet, at Swindon probably 400 feet, in Portland 300 feet, but in the Vale of Pewsey it is very low.

Dirt bed of Portland.

One of the most interesting observations concerning the circumstances which intervened between the marine deposits of oolite and the fresh-water or estuary deposits of the Purbeck clays and limestones, is that of Dr. Buckland and Mr. De la Beche on the *dirt bed* which lies between these groups of strata in the Isle of Portland. This bed is compared by those acute Geologists to black vegetable mould. The stems of cycadeæ and larger coniferæ, which are found in this bed, often "stand erect, and have their roots attached to the black soil in which they grow;" thus presenting us with an ancient submerged forest, for comparison with the more modern submarine forests which in so many points margin the English, Welsh, Scotch, and Irish coasts.

It is concluded by these authors that the Portland rock, whereon these plants are stated to be in the place and attitude of growth, had been raised to become dry land, and then sunk again, under such circumstances as to become covered by fresh water, which produced the Purbeck limestones and clays; and it appears a matter of probable inference that at the same periods the whole Wealden district was submerged under nearly the same circumstances. The absence of conglomerates and dislocations appears to prove that these submersions were effected quietly and gradually; certain beds of oysters show that the waters were at least occasionally brackish, the sea again regained its dominion, and deposited the cretaceous rocks and marine testacea, and finally yielded place again to a lacustrine deposit.

Wealden Formation.

Until the appearance of Mr. Mantell's Works on the Geology of Sussex, the peculiar relations of the vast thickness of sandstones and clays of the interior of Kent, Sussex, and Hampshire, were entirely misunderstood. No one supposed that these immense strata were altogether of a peculiar type, and interpolated amidst the rest of the marine formations, as a local estuary formation, of which only very faint traces can be perceived in other parts of England. Always striving to make particular results harmonize into one general system, Mr. Smith and other Geologists at one time referred the interior sandstones to the "iron sand," and the Weald clay to one of two beds, confused under the title of oaktree clays. This mode of classification seemed, indeed, tolerably consistent with the mineralogical characters of the formations, but was found wholly at variance with their animal and vegetable remains. For these, instead of being fossils of the iron sand and Kimmeridge clay or Gault, were really a peculiar suite of terrestrial and fluviatile exuviæ of which very few traces have been perceived elsewhere.

Mr. Mantell's publications have clearly shown that the true place of the whole Wealden formation is *below* the iron sand or lower green sand, and, probably, immediately *above* the Purbeck limestones, which overlie the Portland oolite.

The only places in England where analogous beds are known to occur, are at the back of the Isle of Wight, in the Isle of Purbeck, along the South side of the Dorset Downs, and in the Vale of Tisbury in Wilts.

Groups of the Wealden formation.

The Wealden formation naturally divides itself into two groups, which give distinct physical features to the Countries which they occupy; and if to these we add the Purbeck limestones below, we have the following order of succession.

Upper group. Weald clay.	Pale blue clay, of considerable but variable thickness, having in the upper part septaria of argillaceous ironstone, and in the lower part beds of the shelly limestone, called Sussex marble.
Middle group. Hastings sands.	Fawn-coloured sand and friable sandstone. (Horsham beds.) Calciferous sandstones, alternating with friable and conglomerate grits, resting on blue clay. (Tilgate beds.) White sand and friable sandstone, alternating with clay. (South sandstone.) Bluish-grey limestone alternating with blue clay and sandstone shale, and some beds of calciferous sandstone. (Ashburnham beds.)
Lower group.	The Purbeck beds, consisting of shelly limestones alternating with clay.

Weald clay.

The Weald clay forms one general valley, most conspicuous on the Northern side, between the elevated central ridges of the Hastings sands, and the chalk downs of Kent, Surrey, Hampshire, and Sussex, from Hythe by Tunbridge, Hartingcombe, Hailsham, to Pevensey.

Hastings sands.

The Hastings sands distinguish themselves by forming a central axis of elevation along what is called the Forest ridge, by Battle, Crowborough, and Tilgate Forest to Horsham: Crowborough, the highest point, is 804 feet above the sea. This arrangement may be studied on Mr. Mantell's and Mr. Smith's sections, but the general axis of elevation is so confused by a number of local disturbances, and is, moreover, so broad a ridge, that its character is often overlooked. Those who suppose the chalk of the Northern and Southern escarpments to have once extended over all the area of the Wealden formation, and to have been subsequently removed by watery violence, have rightly applied to this devastated region, the name of the great denudation.

Whether, in truth, the Purbeck beds should be thus ranked in a separate section, or be considered as the equivalent of the whole argillo-calcareous formation of the Weald, is, perhaps, matter of doubt. It is, however, certain that the most decided analogy prevails between the upper part of the Purbeck series and the marble beds of the Weald clay. We shall now add a few details on these groups in succession, beginning with the Purbeck beds.

Purbeck beds.

These consist of many thin strata of argillaceous limestone, alternating with slaty marls, and form an aggregate of 300 feet in thickness. Mr. Webster de-

scribes the beds of stone as consisting chiefly of shells, usually, but without certainty, referred to the fresh-water genus paludina. They might, with equal confidence, perhaps, be supposed to belong to an ancient littoral genus of the family turbinacea. But a small portion of these calcareous beds is fit for columns, chimney-pieces, and other architectural uses for which the "Purbeck marble" is celebrated. Our cathedrals were formerly supplied from quarries in the very highest part of the series, which are now extinct. The shells in this stone are usually *small* paludiniform shells. According to Mr. Middleton, three *veins* of good stone, not exceeding altogether 17 feet, lie in the midst of alternations of other stone compact or shelly, and black slaty clay, more than 270 feet thick.

Ashburnham beds. The Ashburnham beds, above 100 feet thick, consist of shelly limestone and shale, alternating with blue clay, and containing subordinate beds of ironstone and sandstone. Limestone, of a dark bluish-grey colour, full of immense quantities of bivalve shells, more or less spathose, is the most characteristic deposit of the group. The shale which is associated with this limestone, sometimes contains the same shells in a white friable state. In ancient times the rich ironstone accompanying this limestone was, through the use of the latter as a flux, converted into iron by wood fires, and thus, in part, have the vast forests of Sussex been diminished. The shells are usually supposed to belong to cyrena or cyclas, in accordance with the opinion that the whole Wealden formation is of fluviatile or estuary origin; but this is still an obscure point, and some of the shells appear to resemble nucula. At Poundsford a bed of calciferous Tilgate sandstone is found *under* a bed of the Ashburnham limestone, and the same was found in some of the limestone pits of Lord Ashburnham.

Worth sands. The Worth sands and sandstones afford a fine soft building-stone, extensively dug at Worth, near Crawley. The sandstone is for the most part of a white or pale fawn or yellow colour, and occasionally contains leaves and stems of ferns, arundinaceous plants, and other vegetable reliquiæ. They may be well studied in the cliffs near Hastings.

Tilgate beds. The Tilgate beds consist of three divisions. The lower one is clay or marl, of a bluish-grey colour, alternating with sand, sandstone, and shale, and containing stems of vegetables, and very rarely bones and shells.

The middle division consists principally of large concretional or lenticular masses of a compact calciferous grit, or sandstone lying in sand. The stone is fine grained, of a light grey colour, inclining to blue or green, and is composed of sand, cemented together by about 25 per cent. of crystallized carbonate of lime. Its fractures frequently show glistening faces. The lower portions of this bed form a conglomerate, and contain *pebbles* of quartz and jasper, sometimes *evidently* water-worn. (Of this stone are three or four layers, from 2 or 3 inches to 1½ or 2 feet, associated with sand.) The surface of the blocks is often covered with mammillary concretions. These are the strata from which Mr. Mantell has drawn the astonishing profusion of animal and vegetable remains. The vegetables are wholly of terrestrial origin, mostly of cryptogamous and gymnospermous structure. There are probably no zoophytic remains. The testacea (mostly casts) much resemble the lacustrine genera, paludina, unio, cyrena. Fish-teeth and scales abound, with remains of a land tortoise, a fresh-water and a marine turtle, plesiosaurus, crocodile, megalosaurus, hylæosaurus, iguanodon, and some kinds of aquatic birds.

Irregular alternations of sand and sandstone, of various shades of green, yellow, and ferruginous, the surface often furrowed like the sand on the sea-shore, cover the whole group.

The Horsham beds of sand and friable sandstone, grey, yellow, or ferruginous, with occasional interspersions of ironstone, and a very large proportion of disseminated small linear portions of lignite, form the upper division of the Hastings group, and encircle the immense Tilgate beds. The sandstone is micaceous and ferruginous, and sometimes holds a considerable proportion of calcareous matter. These beds alternate with a stiff grey loam or marl. The lignite is conjectured to have been derived from carbonized ferns.

The Weald clay group, besides its general physical features already mentioned, has little to detain us. The septaria of this clay are composed of a deep red, argillaceous ironstone, and with remains of fishes and cyprides, occur in layers of two or three feet in thickness in the upper divisions of the clay. The shelly limestones, so well known by the name of Sussex marble, appear to occupy chiefly the middle beds of the Weald clay. They occur in layers of a few inches or a foot in thickness, separated from each other by seams of clay or coarse friable limestone. The compact varieties, when polished, exhibit sections of the enclosed shells. These are usually referred to paludina, and have been compared to the recent paludina vivipara, and they are associated with the shelly remains of a minute branchiopode, (cypris?) from which circumstance it is inferred that the Weald clay is a lacustrine deposit. This shelly marble occurs all along the line of the Weald clay from Leighton to Petworth, Newdigate, South of Tilvester hill, and Bethersden in Kent: potamida? and cyrenæ have been collected from this clay. — Weald clay group.

The evidence upon which it is now very generally admitted that the Wealden formation was a fresh-water or estuary deposit, is founded upon a contemplation of the organic remains, and this subject admits of three general observations. — Of fresh-water origin.

First. There is in all the strata of the Wealden formation, whether sandy, argillaceous, or calcareous, an almost entire absence of decided marine genera of shells and zoophyta. In particular, the numerous and characteristic tribes of ammonites and belemnites, of trigoniæ, terebratulæ, and ostreæ, of echinida, stellerida, and polyparia, are entirely absent, a circumstance certainly unparalleled in any section of equal variety among marine strata.

Secondly. What shells there are have most generally the forms of fresh-water or littoral genera, and it may be remarked especially that this kind of evidence bears with most force upon the middle group.

Thirdly. The plants which abound in this middle group are of terrestrial, or marshy, and not of marine origin, and the saurian remains also indicate the littoral or marshy life of those monstrous animals.

We may therefore confidently adopt Mr. Mantell's conclusion of the fresh-water origin of the materials of the Tilgate beds, and suppose these materials to have been deposited in an estuary by one or many rivers; and also refer to a similar *place of deposit*, the lower bed of limestone and clay, and the upper group or Weald clay; but that the *materials* of these argillo-calcareous deposits were also derived from the land is not yet *proved* in the same manner as has been done for the

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arenaceo-calcareous deposits of the forest ridge. Whatever may have been the causes, it is probable that the change from the *truly marine* Portland oolite to the supposed *lacustrine* Purbeck beds is *gradual*, and the same must be said of the change from the Weald clay to the lower green sand. The varying force with which the water-floods of the land were introduced into the supposed estuary or gulf, may, perhaps, explain both gradations of the extreme groups and the determined fresh-water origin of the middle group of the Wealden formation.

Oolitic System.—Foreign Localities.

Range and extent.

The oolitic system is so largely developed in England as to form a very conspicuous if not the principal feature in its Physical Geography, and its extreme ramifications reach the Northern and Western coasts of Scotland, and the Eastern shore of Ireland. But the range of these rocks is still more extensive on the Continent of Europe, and obscure indications of the continuation of the lower formation of lias occur in North America and are repeated in India. In France, a broad belt of oolitic rocks borders on the East the primary rocks of Brittany and La Vendée, and sweeps round the basin of Paris from the coast of Normandy, (Calvados,) by Falaise, Alençon, Lemans, Saumur, Poitiers, Chateauroux, and Nevers, and through Burgundy, Franche-Comté, and Lorraine, till, along a line from Avesnes to Luxemburg, it abuts against the slate mountains of the Ardennes. From Poitiers the oolites continue themselves Westward to La Rochelle, Southward to Angoulême, Perigueux, Cahors, and the vicinity of Montauban. A little discontinuity here occurs, but the oolites of Rhodez and the Cevennes mountains, by continuing themselves South-Westward to Montpellier, Carcassone, and Foix, along the Northern slope of the Pyrenees to Fontarabia, and North-Eastward to Montelimart and Grenoble, and so to the Jura, and South-Eastward to Marseilles and Nice, unite into one irregular mass the whole area of the French oolite. These formations are largely developed in Spain, and, in particular, form a band on the slope of the Pyrenees.

Along the Swiss border of France runs the long calcareous chain of the Jura, and this whole mountain region is a mass of the oolitic rocks. It is therefore generally assumed on the Continent as a type of the system, and the terms Jura-kalk, Jura formation, are exactly equivalent to our oolitic system. This is connected below the alluvial valley of the Saone with the oolites of Burgundy. In its continuation Northward, the Jura ranges pass in a broad belt through Würtemberg, Bavaria, and Franconia, and reach the Maine as it issues from the Bohemian mountains.

The Jura is also connected, by crossing the Rhone below Geneva, with the limestone which follows the range of the Western Alps from Provence through the Tarentaise and Savoy into the Valais, and continues along the Oberland mountains, across the Lakes of Thun, Brientz, Lucerne, and Wallenstadt, and then beneath the Tyrolese and Styrian Alps, by Inspruck and Salzburg, to the neighbourhood of Vienna. Nor is this the end of the enormous range, for the Northern border of the Carpathians about Cracow and Dynow is defined by vast breadths of compact oolite.

On the Southern side of the Alps, the same limestones appear in great force, and stretch through Illyria and Carniola to Trent, and the Lakes Guarda, Iseo, Como, Lugano, and Maggiore.

Besides these immense ranges of rocks of the oolitic area, many smaller detached portions may be seen upon Von Buch's and other Maps, and one in the Northern part of France, around Boulogne, is of particular interest.

It appears, then, that the sea which deposited the oolites floated round, or perhaps covered the spaces where now rise on high the Alps, the Carpathians, the Pyrenees, Auvergne, the Vosges, the Black Forest, and Bohemian mountains, in general corresponding to the basin in which the saliferous system was formed. The original arrangement of the rocks has been in places immensely disturbed, and vast regions have been devastated by floods, yet no doubt the general geographical outlines of the system are nearly what they always were. It may not be easy always, in the present state of knowledge concerning the extent of subterranean movements, to say what were the depths and the shallows of this great ocean; but even toward this very considerable approximations may be made by comparing the mineral and zoological and botanical characters of the deposits in different places.

Divisions of the system.

Notwithstanding their vast extent, it does not appear that the continental oolites are any where subject to greater variation and composition than the English series.

In the North of France most of the groups acknowledged by the English Geologists may be recognised, as the lias, inferior oolite, Bath oolite, forest marble, Oxford clay, coralline oolite, Kimmeridge clay, and even the Portland oolite, (De la Beche, *Geol. Trans.*) and the organic remains are either very similar or identical. But in the vicinity of the granites of Auvergne, it is difficult to distinguish more than the lias, and one great overlying mass of oolites indistinctly divided, except by having in the lower part a ferruginous bed sometimes accompanied by ferruginous sand probably corresponding to that of the inferior oolite.

The Jura shows us distinctly the lias, and a mass of calcareous rocks, sometimes perfectly oolitic, in other places earthy or compact, occasionally interlaminated with clays, but hardly capable of any clear and satisfactory divisions. The lower parts are often ferruginous and sandy, and clearly represent the inferior oolite. The upper parts, nevertheless, by admixture of *chloritic* grains and beds of green sand, appear to represent the upper oolite series of England, until, as may be particularly observed in the Salève, it is difficult not to allow that the oolitic and cretaceous systems are united in the cap beds of the Jura-kalk. This should be compared with the previous notices of green sand below the Portland oolite. The fucoid grits along the line of the Eastern Alps clearly belong to the green sand, and the relations of the hippurite limestone, which is at the top of the alpine kalkstein shows that the causes which in England and the North of France have occasioned *such decided* differences in the oolitic series, and established so many groups, did not obtain in these parts. It is extremely probable that this is merely the difference between littoral and pelagian deposits. In England, generally, the disturbance of a shore is indicated by the more numerous alternations, beds of clay and sandstone, rolled shells, ripple marks, and land plants, and, where these characters go to extreme, the whole formations appear changed to a coal system. Something like this

happens, as before mentioned, at the Porta Westphalica, but the greater part of the oolitic limestone of France, Germany, and the Alps, appears to have been deposited in deeper and more quiet waters. Through all these Countries the *proportion* of limestone to the more mechanical deposits is much greater than the average of the English series, the marks of disturbance are mostly wanting, the lines of division are obliterated, and the products of the land infrequent. Perhaps we may in this way account for the smaller number of organic remains belonging to the Alpine limestones; for if these were eminently pelagian, they should probably contain fewer marine exuviæ, since we have good reason to believe that the deepest parts of the sea, where light can hardly penetrate, and all is dull repose, are almost devoid of organic life. As the borders of a Desert are rich in every vegetable hue and resonant with all the voices of animals, so are the borders of the sea prolific of existence, but the Sahara and the Ocean are equally dead at their centre.

The oolitic texture seems to lose itself in the same manner toward the Alps, amongst which it can be seldom seen, and in general the paucity of organic remains is greatest in the most compact or most crystalline of the varieties of these limestones. The Jura, through its whole range in Würtemberg and Bavaria, uniformly shows upon the lias a cap of rocks associated with sand, and often passing upwards into ferruginous oolite, and the same thing happens above the lias of Hanover and Westphalia.

Solenhofen beds.

In the centre of the German Jura, at Solenhofen and Eichstadt, occur beds of white fissile limestone, now universally employed in lithography, which abound in organic remains, and have been long supposed to be much related to the Stonesfield slates. This relation is, perhaps, not supported by their Geological position, for this is certainly above not only the inferior oolite previously described, but also above a considerable thickness of Jura-kalk, and a variable mass of dolomite. M. Von Dechin appears to think these beds of an anomalous character, as indeed their organic remains testify. The whole of this slaty group is seen to thin out near the mouth of the Altmühl between masses of dolomite, being entirely surmounted by green sand and cretaceous deposits. (Murchison, *Geol. Proceedings.*) The author just quoted inclines to the opinion that the higher members of the oolitic groups of England, have not yet been satisfactorily defined in any part of central Germany. This subject will be soon cleared up by the active and intelligent Geologists of Germany.

Disturbances of the Oolitic System.

The parallelism of beds over large regions, the repetitions of similar rocks at frequent intervals, and the gradual change of the species of organic remains through the whole series, appear to indicate that the long period when the oolitic system was deposited was one in which the ordinary operations of Nature were uninterrupted by paroxysms of igneous violence. On viewing the whole series of these strata, and considering the manner in which their outcrops follow one another, it appears that only a very few instances can be pointed out where any beds of the oolitic system are really unconformed to others of the same system below them. Apparent exceptions to this law are indeed presented by every detailed Geological Map, particularly in the case of the coralline oolite, but this rock appears to have been an irregular and limited deposit. It is, perhaps, hardly enough to justify the term unconformity, to show that some of the upper beds of this system have probably been removed by wasting effects of water before the deposit of the incumbent clay, as at Heddington. One case, however, may be mentioned, at Cave, in Yorkshire, where, amidst the more striking phenomena of unconformity between the oolitic system and the chalk, there appears reason to believe that the deficiency in cornbrash and forest marble systems may be ascribed to a local unconformity of the stratification of the Kelloway rock. Other instances will no doubt be discovered, but they will probably be found equally unimportant.

The case, however, is entirely different when we transport ourselves to the period immediately following the deposit of the oolites. Through a large part of England the line of the outcrop of the chalk, green sand, &c. follows pretty exactly the range of the oolitic system, and of course we must infer that for all those districts the bed and boundary of the sea were not at all changed in position in the interval between the two systems of strata. But at either extremity of the range the plane of the cretaceous system is carried over the edges of the oolites from the upper to the lower part of the system, so that at Bishop Wilton, in Yorkshire, it rests within 25 feet of the top of the red marl.

In Dorsetshire, the chalk and green sand by over extension rest on all the members of the oolite in succession, and at length, in Haldon, actually touch the red marl.

Mr. Murchison, from his interesting observations on the Ord of Caithness, inferred that this granitic mass had been upheaved in a *solid form*, and thus that the contiguous or neighbouring oolitic strata were broken up. The brecciated character so frequent in these limestones is referred to a subsequent recomposition of the fragmented parts. Without dwelling on other cases in the British dominions, we may fairly infer from this important observation, coupled with the former cases, that there was an extensive disturbance and angular movement in the interior of the Earth beneath the Sea in which the oolites had been deposited. Considerable faults, ranging East and West, accompany the elevation of the oolites in Yorkshire.

On the Continent very extensive disturbances, happening at the same era, show that this was indeed a period when the convulsive energies of the subterranean regions were strongly and extensively exerted.

To this period M. Elie de Beaumont refers a very extensive line of dislocations, connected with the elevation of Mont Pilat near Lyons, the Côte d'Or, and the Erzgebirge. It is observed that all these axes of elevation range North-Eastward and South-Westward, and in the regions intermediate between these, marking ridges and lines of undulated stratification may be traced in the same North-Eastern and South-Western direction, particularly on the broad belt of the Jura.

Without insisting upon the exact parallelism ascribed by M. de Beaumont to these lines of disturbance, we are warranted in admitting that to the convulsions at this period, the long range of oolites connected with the ridges of the Jura both in France and Germany, and with the line of the Erzgebirge, owe, if not their actual height above the sea, some of their peculiar physical features. The cretaceous system in the vicinity of these lines of disturbance appears to be unaffected by them, except by the new outlines which were then given to

the embosoming ocean, from which at a later period the chalk, green sand, &c. were deposited.

The oolites which pass North-Westward from Lorraine are probably continuous under the whole of the chalky plains of Picardy, but their superficial outcrop is extinguished by the overextension of the chalk to contact with the slates of the Ardennes, nor is it renewed on the Northern side of those mountains. Yet this case may not happen through any unconformity, but be a consequence of the irregular bed of the ancient sea. Thus, the red sandstone may be covered and concealed by the oolite, and the latter may be hidden below the chalk, and yet there may be no unconformity. This view is supported by the successive coming out in proceeding to the South-East from Avesnes, first of the oolite, then of the keuper, muschelkalk, and red sandstone, from their abutments against the older slates.

Table of Organic Remains in the Oolitic System.

N. B. The different oolitic formations are designated, where known with certainty, by the letters *l*, *m*, and *u*, (lower, middle, upper,) attached to the several localities.

PLANTS. (The names chiefly from Brongniart.)

Family.	Name.	British Localities. In Lias.	British Localities. In Oolites.	Foreign Localities. In Lias.	Foreign Localities. In Oolites.
Algæ	Fucoides furcatus		Stonesfield, *l*.		
	Stockii				Solenhofen.
	encelloides				Ditto.
	undescribed	England.			
Equisetaceæ.	*Equisetum columnare		Whitby, *l*. Brora, *l*.		
	laterale, Phil.		Scarborough, *l*.		
Filices	Glossopteris Nilsoniana			Hör.	
	Phillipsii		Ditto, *l*.		
	Pecopteris Agardhiana			Ditto.	
	polypodioides		Ditto, *l*.		
	denticulata		Ditto, *l*.		
	Phillipsii		Ditto, *l*. Collyweston, *l*.		
	Whitbiensis		Yorkshire coast, *l*.		
	Nebbensis				Bornholm, *l*.
	tenuis				Ditto, *l*.
	Pingelii				Ditto, *l*.
	Reglei				Mamers, *l*.
	Desnoyersii				Ditto, *l*.
	recentior, Phil.		Scarborough, *l*.		
	exilis, Phil.		Ditto, *l*.		
	cæspitosa,* Phil.		Ditto, *l*.		
	cristata, Phil.		Ditto, *l*. Egton, *l*.		
	Neuropteris lobifolia, Phil.		Scarborough, *l*.		
	Sphænopteris hymenophylloides*		Stonesfield, *l*. Whitby, *l*.		
	crenulata		Whitby, *l*.		
	denticulata		Ditto, *l*.		
	Williamsoni		Ditto, ..		
	macrophylla		Stonesfield, *l*.		
	muscoides, Phil.		Yorkshire coast, *l*.		
	digitata, Phil.		Stonesfield, *l*. Whitby, *l*.		
	Tæniopteris latifolia		Ditto, *l*. ditto, *l*.		
	*vittata		Whitby, *l*.	Ditto.	
	Pachypteris lanceolata		Scarborough coast, *l*.		
	ovata		Ditto, *l*.		
	Filicites Bechei				Bornholm, *l*. Helsinborg, *l*.
	Cyclopteris digitata, Lind.		Scarborough, *l*.		
	Beanii, Lind.		Ditto, *l*.		
	auriculata		Ditto, *l*.		
	Clathropteris meniscioïdes			Ditto	Vosges.
	(Phyllites nervulosus, Phil.)		Ditto, *l*.		
Lycopodiaceæ.	Lycopodites patens			Ditto.	
	Williamsoni		Ditto, *l*. Whitby, *l*.		
	falcatus, Lind.		Whitby, *l*. .		
Cycadeæ.	Pterophyllum Williamsoni		Whitby coast, *l*.		
	comptum, Phil.		Scarborough coast, *l*.		
	minus		Scarborough, *l*.		
	Nilsoni		Whitby, *l*.		
	dubium			Ditto.	
	majus			Ditto.	
	Zamites Bechei	Lyme Regis			Mamers, *l*.
	Bucklandii	Ditto			Ditto, *l*.
	lagotis				Ditto, *l*.
	hastata				Ditto, *l*.
	Zamia pectinata		Stonesfield, *l*.		
	patens		Ditto, *l*.		
	longifolia		Scarborough, *l*.		
	penniformis		Ditto, *l*.		
	elegans		Ditto, *l*.		

Family.	Name.	British Localities. In Lias.	British Localities. In Oolites.	Foreign Localities. In Lias.	Foreign Localities. In Oolites.
Cycadeæ	Zamia Goldiæi		Scarborough, *l.*		
	acuta		Ditto, *l.*		
	lævis		Ditto, *l.*		
	Youngii		Ditto, *l.*		
	Feneonis				Seyssel, *l.*
	Mantelli				Ditto, *l.*
	pecten				Ditto, *l.*
	Nilsonia brevis			Hör.	
	elongata			Ditto.	
	Cycadeoidea magalophylla, Brown		Portland, *u.*		
	microphylla, B.		Ditto, *u.*		
Coniferæ	Taxites podocarpioides		Stonesfield, *l.*		
	Brachyphyllum mammillare		Whitby, *l.*		
	Thuytes divaricata		Stonesfield, *l.*		
	expansa		Ditto, *l.* Collyweston, *l.*		
	acutifolia		Stonesfield, *l.*		
	cupressiformis		Ditto, *l.*		
	Coniferæ of uncertain tribes	Whitby, &c.	In lower, middle, and upper oolites.		
Monocotyledoneæ	Bucklandia squamosa		Stonesfield, *l.*		
	Flabellaria viminea		Whitby coast, *l.*		
	Calamites Nilsonii			Ditto.	
Of uncertain tribes	Mammillaria Desnoyersii				Mamers, *l.*

The Valorsine and Tarentaise slaty rocks, supposed by Elie de Beaumont to be of the age of lias, contain plants of the carboniferous epoch. If the Geological situation of these rocks be rightly determined, we must conclude that certain tribes of plants which flourished in the carboniferous epoch, existed in the vicinity of this deposit, under some peculiar circumstances, through the whole of the new red sandstone period, and were finally extinguished at the commencement of the oolitic era. These plants are in a singular state of conservation, the vegetable substances being replaced by talc—perhaps an effect of the igneous agency exerted in elevating the Alps, which is most remarkably exhibited in the granite veins and interposed masses of the Valorsine. The lias along the Alpine chain is frequently prismatized and converted into a kind of slate.

Polyparia.

N. B. The lias contains very few traces of Polyparia. Anthophyllum sessile is described by Goldfuss from "the upper part of the lias," Thurnau.

Family.	Name.	Upper Jura limestone of Wurtemberg, Bavaria, Swisserland, &c.
Fibrosa	Achilleum dubium	Solenhofen.
	cheirotomum	Streitberg.
	muricatum	Ditto.
	tuberosum	Hattheim.
	cancellatum	Ditto.
	costatum	Streitberg.
	Manon peziza	Ditto.
	marginatum	Baireuth.
	impressum	Muggendorf.
	Scyphia cylindrica	Streitberg.
	elegans	Thurnau.
	calopora	Ditto.
	texturata	Giengen.
	* costata	Baireuth.
	verrucosa	Chaumont, Streitberg.
	textata	Legerberg.
	cariosa	Passau.
	polyommata	Streitberg.
	clathrata	Ditto.
	milleporata	Baireuth.
	parallela	Streitberg.
	psilopora	Muggendorf.
	obliqua	Ditto.
	rugosa	Streitberg.
	tenuistria	Ditto.

Family.	Name.	Upper Jura limestone of Würtemberg, Bavaria, Swisserland, &c.
Fibrosa	Scyphia articulata	Muggendorf.
	pyriformis	Streitberg.
	punctata	Ditto.
	radiciformis	Ditto.
	reticulata	Ditto.
	dictyota	Ditto.
	procumbens	Baireuth.
	paradoxa	Amberg, Streitberg.
	empleura	Streitberg.
	stricta	Ditto, Muggendorf.
	Munsterii	Streitberg, Ratisbon.
	propinqua	Streitberg.
	cancellata	Ditto.
	decorata	Muggendorf.
	Humboldtii	Ditto.
	Sternbergii	Streitberg.
	Schlotheimii	Streitberg, Thurnau.
	secunda	Streitberg.
	verrucosa	Ditto, Wurgau.
	Bronnii	Baireuth.
	intermedia	Hattheim.
	Neesii	Streitberg.
	*turbinata	Ditto.
	*clathrata	Ditto.
	celulosa	Osnabruck, Ortenberg.
	Tragos pezizoides	Muggendorf.
	*acetabulum	Streitberg, Randen.
	patella	Randen, Siegmaringen.
	sphæroides	Würtemberg.
	tuberosum	Rabenstein.
	radiatum	Streitberg.
	rugosum	Ditto.
	reticulatum	Ditto.
	verrucosum	Ditto.
	tuberosum	Baireuth.
	Cnemidium lamellosum	Randen.
	stellatum	Ditto.
	striatopunctatum	Ditto.
	rimulosum	Ditto
	mammillare	Streitberg.
	rotatum	Thurnau.
	tuberosum	Caen.
	granulosum	Streitberg.
	astrophorum	Hattheim.
	capitatum	Amberg.
	Siphonia pyriformis	Chaumont.
	Myrmecium hemisphæricum	Thurnau.

The preceding catalogue of fibrous polyparia, extracted from Goldfuss, (*Petrefactenkunde*,) contains, probably, many species which further research will iden-

tify in England. All of them, except when the localities are marked *l*, are to be referred to the upper or middle oolite. All the ascertained British species are comprised in the following singularly short list, which we will venture to say ought to be decupled.

Spongia floriceps, Phil.	Yorkshire	In middle oolite.
clavarioides, Lam.	Wiltshire	Ditto.
Alcyonium ?	Ditto	Ditto.

Family.	Name.	British Localities.	In the Oolites of Würtemberg, Bavaria, France, &c.
Corticifera	Isis, Park	Calne, *m*.	
Cellulifera	Cellepora orbiculata		Streitberg.
	echinata		Haute Saone, *l*.
	Coscinopora sulcata		Swisserland.
	Retepora	Yorkshire, *l*.	
	Flustra	Wiltshire, *l*.	
	Ceriopora radiciformis		Thurnau.
	*dichotoma		Ditto.
	*clavata		Ditto.
	striata		Ditto, Streitberg.
	angulosa		Thurnau.
	alata		Ditto.
	crispa		Ditto.
	favosa		Ditto, Streitberg.
	radiata		Thurnau.
	compressa, Mün		Ditto
	orbiculata		Haute Saone, *l*.
	Aulopora compressa		Rabenstein, Grafenberg, *l*.
	intermedia, Mün		Streitberg.
	decipiens		Buxweiler.
	dichotoma		Streitberg.
	Entalophora cellarioides, Lam.		Normandy, *l*.
	Spiropora tetragona, Lam.		Caen, *l*.
	cæspitosa, Lam	Wiltshire, *l*.	Normandy, *l*.
	elegans, Lam.		Ditto, *l*.
	intricata, Lam.		Ditto, *l*.
	Eunomea radiata, Lam.	Bath, *l*.	Ditto, *l*.
	Chrysaora damæcornis, Lam.	Wiltshire, *l*.	Ditto, *l*.
	spinosa, Lam.		Ditto, *l*.
	Theonea clathrata, Lam.	Ditto, *l*.	Ditto, *l*.
	Idmonea triquetra, Lam.	Ditto, *l*.	Ditto, *l*.
	Alecto dichotoma, Lam.	Ditto, *l*.	Ditto, *l*.
	Berenicea diluviana, Lam.	Ditto, *l*.	Ditto, *l*.
	Smithii, Phil.	Scarborough *l*.	
	Terebellaria ramosissima, Lam.	Bath, *l*.	Ditto, *l*.
	antilope, Lam.		Ditto, *l*.
	Thamnastena Lamourouxii, Le Sauvage		Ditto, *l*.
	Millepora straminea, Phil.	Scarborough, *l*.	
	dumetosa, Lam.		Ditto, *l*.
	corymbosa, Lam.		Ditto, *l*.
	conifera		Ditto, *l*.
	pyriformis		Ditto, *l*.
	macrocaulis		Ditto, *l*.
	Conodictyum striatum		Streitberg.
Lamellifera	Madrepora limbata		Heidenheim.
	Pavonia tuberosa ?	Wiltshire, Yorkshire, *m*.	
	Explanaria mesenterina, Lam.		
	lobata		Baireuth.
	alveolaris		Ditto.
	Agaricia rotata		Randenberg.
	boletiformis		Soissons.
	crassa		Randen.
	granulata		Hattheim.
	Meandrina astroides		Giengen.
	tenella		Ditto.
	Soemmeringii		Near Basle.
	virgineum		Chaumont.
	Astræa microconos		Muggendorf.
	concinna		Giengen.
	oculata		Ditto.
	alveolata		Heidenheim.
	helianthoides		Ditto, Giengen.
	confluens		Ditto, ditto.
	rosacea		Basle.
	caryophylloides		Giengen
	cristata		Ditto, Heidenheim.
	agaricites		Salzburg.
	sexradiata		Giengen.
	limbata		Ditto.
	formosa		Salzburg.
	pentagonalis, *m*.		Hattheim.

Family.	Name.	British Localities.	In the Oolites of Würtemberg, Bavaria, France.
Lamellifera	Astræa gracilis, *m.*		Boll.
	explanata		Würtemberg.
	tubulosa		Ditto.
	tubulifera, Phil.	Wiltshire, *m.* Yorkshire, *m.*	
	favosioides, Smith	Wiltshire, *m.* Oxon, *m.* Yorkshire, *m.*	
	inæqualis, Phil.	Malton, *m.*	
	micrastron, Phil.	Yorkshire. *m.*	
	arachnoides, Phil.	Malton, Wiltshire, &c. *m.*	
	several other species, Smith,	in the lower oolite.	
	Lithodendron elegans		Ditto.
	compressum		Ditto.
	granulosum		Salzburg.
	Caryophyllia annulata, Flem.	Wiltshire, *m.*	
	cylindrica, Phil.	Malton, &c., Yorkshire, *m.*	
	truncata, Lam.		Normandy, *l.*
	Brebissonii, Lam.		Ditto.
	convexa, Phil.	Whitby coast, *l.*	
	other species	Wiltshire, Yorkshire, &c. *l.* and *m.*	Ditto.
	Cyathophyllum tintinnabulum		Banz, Bamberg.
	mactra		Ditto, ditto.
	Turbinolia dispar, Phil.	Malton, &c. *m.*	
	cuneata		Salzburg.
	other species	Near Bath, *l.*	
	Anthophyllum turbinatum		Hattheim, Heidenheim.
	obconicum		Ditto, ditto.
	sessile		Thurnau.
	Fungia orbiculites, Lam.	Bath, *l.*	Normandy, *l.*
	lævis		Swisserland.
	numismalis		Giengen.
	polymorpha		Dauphiné.
	undulata		Salzburg.
	discoidea		Ditto.

Radiaria.

Family.	Name.	Foreign and British Localities in Lias.	British Localities in Oolite.	Foreign Localities in Oolite.
Crinoidea	Eugeniacrinus caryophyllatus, G.			Baireuth, Würtemberg, Swisserland.
	nutans, G.			Streitberg, Muggendorf, Swisserland
	compressus, G.			Baireuth, Würtemberg.
	pyriforme, M.			Randenberg
	moniliforme, M.			Baireuth, Swisserland.
	Hoferi, M.			Streitberg, ditto
	Solanocrinus costatus, G.			Giengen, Heidenheim.
	scrobiculatus, M.			Thurnau, Streitberg.
	Jaegeri, G.			Baireuth.
	Encrinites echinatus, Schl.			Haute Saone.
	Pentacrinus briareus	Whitby, Lyme, Boll, &c.		
	subangularis	Rutland	Oxfordshire, *l.*	
	basaltiformis	Alsace.		
	tuberculatus	Ditto.		
	caput Medusæ	Lyme, Whitby, Alsace.	Yorkshire, *l.* Wiltshire, *l.*	Alsace.
	scalaris, G.		Wiltshire, *l.*	
	cingulatus, M.			Streitberg, Thurnau.
	pentagonalis, G.	Boll		Ditto, ditto.
	moniliferus, M.	Baireuth.		
	subsulcatus, M.	Ditto.		
	subteres, M.			Streitberg.
	paradoxus, G.			Baireuth. Würtemberg.
	Jurensis, M.			Haute Saone.
	Apiocrinus rotundus		Bath, *l.*	Alsace. Würtemberg.
	elongatus		Ditto. *l.*	Soleure, Befort.
	rosaceus, Schl.			Soleure. Würtemberg.
	mespiliformis, G.			Heidenheim, Giengen.
	Milleri, Schl.			Hattheim. Würtemberg.
	flexuosus, G.			Würtemberg.
	obconicus, G.		Ditto.	
	Rhodocrinus? echinatus, G.		Malton, *m.*	Amberg, Swisserland.
Stellerida	Comatula pinnata, G.			Solenhofen.
	tenella, G.			Ditto.
	pectinata, G.			Ditto.
	filiformis, G.			Ditto.
	undescribed, Phil.	Frethern, Gloucestershire.		
	Ophiura Milleri, Phil.	Staithes, Yorkshire.		
	speciosa, M.			Ditto.
	carinata, M.			Ditto
	Asterias lumbricalis, Schl.	Walzendorf, Lichtenfels.		
	lanceolata, G.	Lichtenfels.		
	arenicola, G.	Porta Westphalica, *l.*		

Family.	Name.	Foreign and British Localities in Lias.	British Localities in Oolite.	Foreign Localities in Oolite.
Stellerida	Asterias Jurensis, M.			Baireuth, *m* and *l*.
	tabulata, G.			Streitberg.
	scutata, G.			Ditto, Heiligenstadt.
	stellifera, G.			Streitberg.
	prisca, G.	Wasseralfingen, Würtemb.		
	other species		Bath, *l*. Malton, *m*. Yeovil, *l*.	
Echinida	Cidaris maximus, M			Baireuth.
	Blumenbachii, M.	Pretzfeld		Thurnau, Muggendorf.
	nobilis, M.			Baireuth.
	elegans, M.			Ditto.
	moniliferus, G.			Swisserland.
	marginatus, G.			Bavaria, Swisserland.
	coronatus, G; florigemma, Phil.		Wiltshire, *m*. Yorkshire, *m*.	Thurnau, Streitberg.
	propinquus, M.			Streitberg.
	glandiferus, G			Altdorf, Ramlen.
	Schmidelii, M.			Dischingen.
	Buchii, M.			Enneberg in Tyrol.
	crenularis, G			Swabia, Swisserland.
	subangularis, G.			Baireuth.
	variolaris, G.			Streitberg, Ratisbon.
	vagans, Phil.		Somersetshire, *l*. Yorkshire, *l*. Yorkshire, *m*. *l*.	
	intermedia, Phil.	Spines of Cidaris	Yorkshire, Wilts, *m*.	
	monilipora, Phil.	Somersetshire and Yorkshire.	Yorkshire, *m*.	
	other species		Near Bath, *l*.	
	Echinus germinans, Phil		Yorkshire, *m*. Yorkshire, *l*.	
	lineatus, G.			Regensburg, Basle.
	excavatus, Leske.			Regensburg.
	nodulosus, M.			Baireuth.
	hieroglyphicus, G.			Regensburg, Thurnau.
	sulcatus, G			Near Baireuth, &c.
	Galerites depressus, Lam.		Yorkshire, *m*. *l*. Bath *l*. Haute Saone, *m*.	Bavaria, Wurtemberg.
	speciosus, M.			Heidenheim.
	patella, M.		Oxfordshire, *l*. Normandy, *l*.	
	Nucleolites granulosus, M.			Amberg, Streitberg.
	semiglobus, M.			Pappenheim, Manheim.
	excentricus, G.			Kehlheim.
	canaliculatus, G.			Staffelberg.
	scutatus, G			Swisserland.
	*testudinarius, G.			Baireuth.
	columbaria, G.			North of France, *l*.
	Clypeus sinuatus, Leske		Oxfordshire, *m*. *l*. Somersetshire, *l*. Yorkshire, *m*.	
	emarginatus, Phil.		Yorkshire, *m*.	
	dimidiatus, Phil.		Ditto, *m*.	
	clunicularis, Smith		Yorkshire, *l*. Normandy, *l*. Bath, *l*. Yorkshire, *m*. Bath, *m*. &c.	
	orbicularis, Phil.		Yorkshire, *l*.	
	semisulcatus, Phil.		Ditto, *l*. *m*.	
	Spatangus ovalis, Phil.		Scarborough, *m*.	
	intermedius, M.			Blaubeuren, Wurtemberg.
	retusus, Lam.			Blaubeuren.
	carinatus			Baireuth, Wurtemberg.
	capistratus			Baireuth.
	Clypeaster pentagonalis, Phil.		Malton *m*.	

CONCHIFERA. (The names chiefly from Sowerby.)

Family.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
Plagymyona	Pholas recondita, Phil.			Malton.	
	compressa			Oxford	Heddington.
	Gastrochæna tortuosa		Bath, Yorkshire.		
	Panopæa gibbosa		Yorkshire, Dundry.		
	intermedia		Dundry.		
	Pholadomya Murchisoni	In Strasburg Mus.	Brora, Normandy, Yorkshire, Savoy	Yorkshire.	
	lirata	Normandy	Dundry, Haute Saone.		
	deltoidea		Near Bath, Scarborough	Ditto.	
	simplex, Phil			Cave, Scarborough.	
	obsoleta, Phil.			Scarborough.	
	obliquata, Phil.	Yorksh. Gundershofen	Yorkshire.		
	ovalis		Ditto.	Normandy.	Portland. (Conyb.)
	acuticosta		Ditto.	Angoulême, Cahors.	
	nana, Phil.		Ditto.		
	producta		Ditto, Bath.		
	fidicula		Yorksh. Somers. Savoy.		
	obtusa		Dundry.		

Family.		In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
Plagymyona	Pholadomya ambigua	S of France, Soleure, Bahlingen	Dundry	Normandy.	
	aequalis		Normandy		? Weymouth.
	gibbosa	Normandy, Soleure.			
	Protei, Bt.				Havre.
	Mya v. scripta	Yorkshire.	Bedford, Brora, Alsace.		
	literata		Bath, Yorkshire	Brora, Yorkshire.	
	angulifera		Bath, Alsace?		
	calceiformis, Phil		Yorkshire.	Yorkshire.	
	dilata, Phil.		Ditto.		
	aequata, Phil.		Ditto.		
	depressa			Yorkshire? Havre	Yorkshire.
	mandibulata				Angoulême.
	Lutraria Jurassi, Bt.		Ligny.		
	Mactra ———		Brandsby, Yorkshire.		
	Amphidesma decurtatum, Phil.		Yorkshire coast, Bath.		
	recurvum, Phil			Yorkshire	Havre.
	securiforme, Phil		Ditto, ditto.		Ditto.
	donaciforme, Ph.	Whitby coast.			
	rotundatum, Phil.	Whitby coast, Bahlingen, Wahlhaeuserhof.			
	Corbula cardioides, Phil	Yorkshire coast, Bas Rhin, Meurthe.	Westow in Yorkshire.		
	depressa, Phil.		Yorkshire.		
	obscura		Brora.		
	curtansata, Phil.			Ditto.	
	Sanguinolaria undulata		Brora, Scarboro', Bath	Scarborough.	
	elegans	Yorkshire, Lincolnshire.			
	Corbis uniformis, Phil.	Whitby.			
	laevis			Yorkshire.	
	ovalis, Phil.			Ditto.	
	Tellina ampliata, Phil.			Ditto.	
	Psammobia laevigata, Ph.		Yorkshire	Ditto.	
	Lucina despecta, Phil.		Ditto.		
	crassa, Phil.			Ditto.	
	lirata, Phil.			Ditto.	
	Crassina, or Astarte minima, Phil.	Whitby coast.	R. H. Bay, Yorkshire.	Haute Saone.	Haute Saone.
	elegans		Yorkshire coast.		
	lurida		Gloucestershire.	Scarborough.	
	excavata		Dundry.		
	trigonalis		Ditto.		
	ovata, Smith			Yorkshire, N. Wilts.	
	orbicularis		Ancliff.		
	pumila		Ditto.		
	aliena, Phil.			Malton.	
	extensa, Phil.			Ditto.	
	carinata, Phil.			Yorkshire.	
	lineata			Heddington.	
	cuneata				Chilmark, near Aylesbury.
	planata		Normandy.		
	rugata		Ditto.		
	imbricata		Ditto.		
	Voltzii, Haen.		Vesoul? Banz.		
	varicosa		Felmersham.		
	Venus ———	Yorkshire	Yorkshire, Bath.	Yorksh. Normandy, &c.	
	Cythera dolabra, Phil.		Ditto.	Yorkshire.	
	trigonellaris, Voltz.		Gundershofen		
	lucinea, Voltz.		Ditto.		
	cornea, Voltz		Ditto.		
	Pullastra recondita, Phil.		Yorkshire.		
	oblata, Ph.		Ditto.		
	undetermined	Whitby.			
	Cardium truncatum	Whitby coast.			
	cognatum, Phil.		Ditto.		
	acutangulum, Ph.		Ditto.		
	incertum, Phil.		Ditto.		
	gibberulum, Phil.		Ditto.		
	striatulum, Phil.		Ditto.		
	dissimile		Collyweston?	Brora	Portland, near Aylesbury, &c.
	semiglabrum, Ph.		Yorkshire.		
	citrinoideum, Ph.		Ditto.		
	lobatum, Phil.			Yorkshire	
	striatulum		Yorkshire, Brora.		
	multicostatum, Beau.	Whitby			
	Cardita similis		Dundry, Yorkshire.	Ditto.	

Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
Plagymyona	Isocardia rostrata		Cotswolds.		
	excentrica, Voltz.				Portland, Kimmeridge, Haute Saone.
	concentrica		Yorkshire.		
	nitida, Phil.		Ditto.		
	minima		Ditto, Wilts.		
	striata, Dorbigny				Ditto, ditto, ditto.
	angulata, Phil.		? Yorkshire.		
	tumida, Phil.			Yorkshire.	
	rhomboidalis, Phil.			Ditto.	
	tenera		Kelloway in Wilts.		
	Hippopodium ponderosum	Whitby coast, South of England		Ditto.	
	Trigonia literata, Y. and B.	Whitby coast.			
	navis, Lam.		Gundershofen.		
	costata		Bath, Yorksh. Alsace.	Ditto, Oxfordshire.	
	striata	Figeac, S. of France	Yorkshire, Dundry.		
	elongata		Alsace, Wilts.	Normandy.	
	duplicata		Sodbury, Normandy.		
	angulata		Somersetsh. Yorksh.		
	conjungens, Phil.		Yorkshire.		
	imbricata		Ancliff.		
	cuspidata		Ditto.	Haute Saone.	
	pullus		Ditto.		
	clavellata		Bath, Yorksh. Brora.		
	gibbosa				Portland, Tisbury.
	incurva, Benett.				Tisbury.
	Unio ? crassissimus	Lincolnshire, &c.			
	crassiusculus	Yorkshire.			
	Listeri	Ditto.	Middle & S. of England.		
	concinnus	Yorkshire, Bath, Gmündt.	Bath.		
	peregrinus, Phil.		Yorkshire, Bath, &c.		
	abductus, Phil.	Yorkshire.	Yorkshire.		
	Modiola lævis	South Wales.			
	depressa	Central and Southern England.			
	minima	Ditto, ditto.			
	Hillana	South Wales, Whitby.			
	scalprum	Whitby coast, West of Scotland, &c.			
	plicata		Bath, Collyweston, Chanar.		
	cuneata		Scarborough, Lincolnsh.		
	imbricata		Yorkshire, Bath.		
	ungulata		Yorkshire coast	Malton.	
	aspera		Ditto.		
	reniformis		Bath.		
	gibbosa		Ditto, Chanar.		
	bipartita			Yorkshire, Brora.	
	pulchra, Phil.			Scarborough, Brora.	
	subcarinata, Lam.			Normandy.	
	elegans		Normandy.		
	tulipea, Lam.			North of France.	
	pallida			Brora.	
	livida, Goldf.		Chaufour.		
	ventricosa, Goldf.		Soleure.		
	inclusa, Phil.			Malton.	
	Lithodomus		Bath, North of France.		
	Mytilus pectinatus				Weymouth, Thame, Rochelle
	cuneatus, Phil.		Whitby coast.		
	amplus		Bath.		
	sublævis		Felmersham.		
	solenoides				Cahors.
	Nucula ovum	Whitby.			
	complanata, Phil.	Ditto.			
	variabilis		Bath, Yorkshire.		
	lachryma		Ditto.		
	axiniformis, Phil.		Yorkshire.		
	claviformis	South of France	Northamptonshire.		
	mucronata		Ancliff, near Bath.		
	elliptica, Phil.			Scarborough.	
	nuda, Y. and B.			Ditto.	
	pectinata		Wilts.	Normandy.	
	myoidea	Mende, Banz.			
	Hammeri, Defr.		Gundershofen.		
	acuminata, V. Buch		Wisgoldingen.		
	lobata, V. Buch		Mitzingen, Bopfingen.		

Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite
Plagymyona	Nucula suboralis, Goldf.		Wasseralfingen.		
	rostrata		Ditto.		
	elongata		Ditto.		
	arcacea		Banz, Baireuth.		
	Pectunculus minimus		Ancliff.		
	oblongus		Ditto.		
	Arca quadrisulcata			Malton.	
	æmula, Phil.			Ditto.	
	pulchra		Ditto, Rochelle.		
	trigonella, Hæn.		Wasseralfingen.		
	elongata, Hæn.		Ditto.		
	rostrata, Hæn.		Ditto.		
	Cucullæa oblonga		Collyweston, Dundry.	Ditto.	
	elongata		Gloucestershire.	Yorkshire.	
	reticulata, Phil.		Yorkshire coast.		
	cancellata, Phil.		Ditto.		
	imperialis, Bean.		Ditto.		
	cylindrica, Phil.		Yorkshire.		
	minuta		Ancliff.		
	rudis		Ditto.		
	contracta, Phil.			Malton.	
	triangularis, Phil.			Ditto.	
	concinna, Phil.			Scarborough.	
	pectinata, Phil.			Malton.	
	decussata		Normandy.		
	Pecten squamosus, V. Buch	Between Nuremberg and Augsburg.			
	contrarius, V. B.	Wittberg.			
	canaliculatus, G.	Culmbach.			
Mesomyona	Pinna folium, Y. and B.	Whitby coast.			
	granulata, Bt.	Alsace, Aromanche.	La Rochelle.		
	quadrivalvis, Bt.	Alsace.			
	mitis, Phil.			Scarborough.	
	lanceolata			Scarborough coast.	
	cuneata, Bean		Near Coxwold, Yorksh.		
	pinnigena		Normandy	Normandy.	
	Trigonellites, or Aptychus antiquatus, Phil.			Malton, Yorkshire.	
	politus, Phil.			Scarborough.	
	discus			Solenhofen.	
	lævis	Banzberg near Amberg.			
	bullatus, V Meyer	Banz, Boll.			
	elasma, V. Meyer	Ditto, ditto.			
	Gervillia lata, Phil.		Yorkshire coast.		
	acuta		Collyweston, Yorkshire.		
	aviculoides		Gundershofen, Boll, Germs, Nuremberg, Dundry.	Oxford, Yorkshire.	
	pernoides, Desl.		Normandy	Normandy.	
	siliqua, Desl.		Ditto	Ditto.	
	monotis, Desl.		Ditto.		
	costellata, Desl.		Ditto.		
	Avicula lanceolata	Lyme.			
	elegantissima, Phil.			Malton.	
	tonsipluma, Phil.			Ditto.	
	ovalis, Phil.			Ditto.	
	expansa, Phil		Near Malton	Ditto.	
	Braamburiensis.		Scarborough.	Brora, Scarborough.	
	inæquivalvis	Yorkshire coast, Lyme, Baireuth, Harz, Gundershofen	Yorkshire coast, Normandy, Banz, Scheppenstedt.		
	cygnipes, Phil.	Whitby coast.			
	ovata		Stonesfield.		
	costata		Bath, Normandy.		
	echinata	? Yorkshire.	Bath, Lincolnshire.		
	Meleagrina Cadomensis, Defr.		Caen.		
	Plagiostoma Hermanni	Yorkshire, Bath, Alsace.			
	giganteum	Bath, Yorkshire, Gundershofen, &c.			
	rusticum	Mutau		Yorkshire.	
	semilunare	Alsace.			
	punctatum	South Wales, Figeac.	Normandy, Dundry.		
	pectinoideum	Whitby, Pickeridge, Vachingen.			
	concentricum	West of Scotland.			
	duplicatum	Rochfeldau, Bath.	Normandy.	Ditto.	

Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
Mesomyona.	Plagiostoma læviusculum			Yorkshire, Oxfordshire, South of France.	
	rigidum			Oxfordshire, Yorksh. France.	
	rigidulum, Phil.		Scarborough.		
	cardiiforme		Yorkshire, Gloucestersh.		
	interstinctum, Phil.		Yorkshire.		
	ovale		Bath, Mauriac.	Streitberg.	
	obscurum			Kelloways.	
	sulcatum	South of France.			
	transversum, V. Buch.		Stufenberg, Bopfingen.		
	Lima gibbosa		Bath, Normandy.		
	rudis		Yorkshire	Malton, &c. Oxford, Brora.	
	proboscidea		Yorkshire, Dundry, Normandy, Soleure, Baireuth, Basle.		Weymouth, Neufchatel.
	antiqua	Middle and South of England, France.			
	Pecten lamellosus.				Chicksgrove, Thame.
	sublævis, Y. & B.	Whitby coast.			
	æquivalvis	Yorkshire coast, Avalon.	Bath, Gloucestershire.		
	dentatus	Bollerbad, Leicestersh.			
	virguliferus, Phil.	Germany.	Whitby coast.		
	rigidus.		Near Bath.		
	lens		Bath, Haute Saone.	Oxford, Malton.	
	obscurus		Stonesfield, Normandy.		
	fibrosus		Bath.		
	laminatus		Ditto, Stonesfield.		
	annulatus		Felmersham.		
	barbatus	Bath, Normandy	Dundry.		
	abjectus, Phil.		Yorkshire	Oxford, Yorkshire.	
	vagans		Bath, Yorkshire	Yorkshire.	
	demissus, Phil		Yorkshire.	Ditto.	
	similis		Haute Saone	Oxford.	
	vimineus			Ditto, Yorkshire, &c.	
	cancellatus, Bean			Yorkshire.	
	inæquicostatus, Phil.			Oxford and Yorkshire.	
	? corneus		Normandy.		
	Monotis salinaria, Bron.			Regensburg.	
	similis, Mun.			Pappenheim.	
	decussata, Mun.		Hildesheim, Buckeburg, &c.		
	concinnus, G.		Minden, Wurtemberg.		
	Ostrea læviuscula	Bath, Amberg.			
	Marshii		Felmersham. Alsace.	Yorkshire, Normandy.	
	palmetta		Bath, Normandy, Alsace.		
	acuminata		Bath, Oxon, North of France.		
	solitaria		Bath, Yorkshire.	Weymouth, Yorkshire, Havre.	
	Meadii		Bath.		
	obscura		Ditto.		
	costata		Ditto, North of France, Buxweiler.		
	sulcifera, Phil.		Western Yorkshire, Wilts, Haute Saone.		
	rugosa		Bath.		
	gregarea			Wilts, Oxon, Weymouth.	
	duriuscula, Bean.			Yorkshire.	
	inæqualis			Scarborough.	
	undosa, Bean			Ditto.	
	archetypum			Ditto.	
	deltoidea				Havre, Oxfordshire, Yorkshire.
	expansa				Chicksgrove, &c.
	minima, Desl.			Normandy.	
	plicatilis			Ditto. (De Caum.)	
	*carinata, Lam.			Ditto.	
	pectinata			North of France. (Bo-Haye.)	
	pennaria			Ditto, ditto.	
	flabelloides, Lam.			North of France.	
	tubulifera, Phil. M. S.		Ditto.		
	Ostrea irregularis, Mün.	Amberg.			
	ungula, Mün.	Banz, Amberg.			

Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
Mesomyona	Ostrea synama, Mün.	Baireuth.			
	simplicata, Mün.	Ditto.			
	rimosa, V Buch.	Bahlingen.			
	Exogyra digitata			Wilts.	
	mima, Phil.			Yorkshire.	
	crassa		Bath.		
	reniformis, Goldf.		Westphalia.		
	Gryphæa incurva	Bath, Lincoln, Bayeux, Metz, Scotland.			
	cymbium	Figeac, Amberg	? Caen.		
	depressa, Phil.	Yorkshire.			
	obliquata	Bath, Scotland, South of France.			
	Maccullochii	Scotland, Yorkshire, Bath, Normandy.			
	gigantea	Gloucestershire	Ilminster.		
	gigas, Schl.	Mezieres, near Caen.			
	dilatata			Wilts, Yorkshire, Haute Saone, &c.	
	bullata			Lincolnsh. Yorksh. Brora.	
	inhærens, Phil.			Yorkshire.	
	nana			Oxford, Brora, North of France.	
	chamæformis, Ph.			Yorkshire, Brora.	
	minuta		Bath.		
	cymbina			Kelloway Bridge.	
	virgula, Def.			Havre, Weymouth, Oxford, South of France.	
	lituola, Lam.		North of France.		
	columba, B ?		Northamptonshire.		
	Plicatula spinosa	Yorkshire, Bath, Hebrides, Normandy.	Gundershofen.		
	squamosa, Goldf.		Elligser, Brink.		
	Inoceramus dubius	Whitby coast.			
	Posidonia Bronnii, Goldf.	Ubstadt, near Bruchsal.			
	Perna quadrata		Yorkshire	Yorksh. Northamptonsh.	
	isogonoides, Gold		Gundershofen	Vaches Noires, Germs.	
	Crenatula ventricosa	Yorkshire, Bosworth.			
Brachiopoda	Lingula Beanii, Phil.		Yorkshire, Gundershofen.		
	another species	Waldenheim, Bas Rhin.			
	Orbicula reflexa	Yorkshire coast.			
	radiata, Phil.			Malton.	
	granulata		Bath.		
	latissima		Yorkshire.		
	Spirifera Walcottii	Bath, Yorkshire, Hebrides, South of France			
	3 other species	Bath. (Smith.)			
	verrucosa, V. Buch	Würtemberg.			
	granulosa, Goldf.	Ditto.			
	Terebratula punctata	Rutland, Leicestershire.		?	
	ornithocephala	Lyme, Figeac	Near Caen, Jura	Yorkshire, Wilts.	
	lampas	Lyme.			
	serrata	Ditto.			
	acuta	Yorkshire.			
	bidens, Phil.	Ditto, Gloucestershire, Alsace, Würtemberg			
	triplicata, Phil.	Yorkshire, Wurtemberg, Thurnau.			
	trilineata, Y. & B.	Yorkshire	Near Stokesley.		
	crumena	Bath.			
	tetraëdra	Rutland, Lincolnshire, Yorkshire.	Aynho.		
	obovata		Bath, Wilts.		
	intermedia		Bath, Lincolnshire, Yorkshire, Alsace	Yorkshire.	
	digona		Bath, Wilts, Caen.		
	globata		Yorkshire, Nunney	? Ditto.	
	perovalis		Bath, Grantham.		
	bullata		Near Frome.		
	emarginata		Ditto.		
	maxillata		Near Bath.		
	sphæroidalis		Dundry.		
	cornuta		Ilminster.		
	resupinata		Ditto.		
	triquetra		Felmersham, Bedfordsh.		
	coarctata		Bath.		
	reticulata		Frome.		
	hemisphærica		Ancliff.		
	rudis		Amberg.		
	ovata			Ditto.	
	bucculenta			Ditto.	

Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
Brachiopoda.	Terebratula ovoides		Yorkshire	Brora.	
	spinosa		Bath, Yorkshire, Chanar, Jura.		
	media		Bath, Oxon, Jura.		
	orbicularis		Near Bath.		
	fimbria		Cheltenham.		
	plicatella		Near Bridport.		
	obsoleta		Bath, Yorkshire, Jura.		
	concenna		Aynhoe.		
	aspera, Kœnig		Bath.		
	flabellula		Ancliff.		
	furcata		Ditto.		
	socialis, Phil.			Yorkshire.	
	inconstans				Oxford, Weymouth.
	impressa, Schl.			Hohenzollern, Stufenberg, Thurnau.	
	nucleata, Schl.			Ditto.	
	plicata, Lam.			Streitberg.	
	loricata, Schl.		Baireuth, Thurnau.		
	spinosa, Schl.		Blomberg, near Donaueschingen.		
	alata, Lam.			Hohenzollern, Neresheim.	
	grunas, Herault		Caen.		
	trilobata, Mün.		Porta Westph. Bavaria.		
	MOLLUSCA.				
Gasteropoda.	Patella discoides, Schl.		Gundershofen.		
	lævis	Whitby.			
	rugosa		Hampton, Gloucestersh.		
	ancyloides		Ancliff.		
	nana		Ditto.		
	lata		Stonesfield.		
	papyracea, Goldf.	Banz.			
	Emarginula tricarinata		Ancliff.		
	scalaris		Ditto.		
	Fissurella clathrata		Ditto.		
	Pileolus plicatus		Ditto.		
	lævis		Ditto.		
	Bulla elongata, Phil.			Scarborough.	
	Actæon retusus, Phil.			Ditto.	
	glaber, Phil		Yorkshire coast.		
	humeralis, Phil		Ditto.		
	cuspidatus		Ancliff.		
	acutus		Ditto.		
	Auricula Sedgvici, Phil.		Blue Wick, Yorkshire.		
	Cirrus carinatus	Cheltenham.			
	Leachii		Dundry.		
	nodosus		Ditto, Yeovil.		
	cingulatus, Phil.			Ditto.	
	depressus, Phil.			Ditto.	
	Solarium calix, Bean.		Yorkshire.		
	conoideum				Portland, I.
	Delphinula coronata		Ancliff.		
	other species		Yorkshire.	Yorkshire.	
	Trochus and Pleurotomaria duplicatus	Alsace.			
	similis	South of England	Dundry.		
	imbricatus	Cheltenham, South of France, Soleure	Normandy.		
	anglicus	Bath, Yorkshire, Thionville, Banz	Haute Saone, Sherborn.		
	ornatus	North of France	Dundry, Normandy.		
	granulatus		Yorkshire	Ditto.	
	pyramidatus, Bean		Blue Wick, Yorkshire.		
	bisertus, Phil.		Ditto.		
	monilitectus, Phil.		Ditto.		
	concavus		Little Sodbury, Normandy.		
	duplicatus		Little Sodbury, Gundershofen, Banz		
	dimidiatus		Little Sodbury.		
	punctatus		Dundry, Normandy.		
	elongatus		Dundry, Wiltshire, Normandy.		
	abbreviatus		Dundry, Normandy.		
	fasciatus		Ditto, ditto.		
	sulcatus		Ditto, ditto.		
	bicarinatus		Ditto, ditto.	Ditto.	
	tornatilis, Phil.			Ditto.	

Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
Gasteropoda	Trochus & Pleurotomaria guttatus, Phil.			Yorkshire.	
	Gibbsii			Normandy.	
	moliciformis, Stahl.		Stufenberg.		
	reticulatus		Normandy	Weymouth, Oxon.	
	decorata, V. Buch.		Neuhausen.		
	rugatus, Benett				Tisbury.
	Turbo unicarinatus, Bean		Blue Wick, Yorkshire.		
	lævigatus, Phil.		Ditto		
	obtusus		Ancliff.		
	undulatus, Phil.	Yorkshire coast.			
	ornatus		Dundry, Gundershofen.		
	sulcostomus, Phil.			Hackness, Yorkshire.	
	funiculatus, Phil.			Malton.	
	muricatus			Scarborough, Wiltshire, Weymouth.	
	rotundatus		Normandy.		
	costarius, D.			France.	
	trochiformis, Schl.	Boll.			
	Phasianella cincta, Phil.		Scarborough.		
	angulosa		Porta Westphalica, Hæn.		
	Rissoa lævis		Ancliff.		
	acuta		Ditto.		
	obliquata		Ditto.		
	duplicata		Ditto.		
	Turritella quadrivittata, Phil.		Blue Wick, Yorkshire.		
	muricata		Blue Wick	Oxford, &c.	
	excavata				Chilmark, &c.
	echinata, V. Buch.		Banz, Langheim.		
	Nerinæa cingenda		Yorkshire, Lincolnshire, Bath	Yorkshire.	
	tuberculata, Blain.	Near Auxerre		Auxerre.	
	mosæ, Des			? St. Mihiel, Pouilly.	
	Cerithium ? intermedium, Hæn.		Near Minden.		
	Terebra melanioides, Phil.			Malton and Pickering.	
	granulata, Phil.		Scarborough coast	Yorkshire.	
	vetusta, Phil.		Ditto		
	Natica tumidula		Dundry, Yorkshire.		
	adducta		Blue Wick, Yorkshire.		
	——— Smith		Lincolnshire, Bath, &c.		
	arguta, Smith			Yorkshire, Wilts, &c.	
	nodulata, Phil.			Malton.	
	cincta, Phil.			Ditto.	
	Melania ? Heddingtonensis		Yorkshire, Dundry, Caen; Haute Saone.	Yorkshire, Oxon, Weymouth, Kilheim.	Havre, North Wiltshire
	striata	? Lymington	Yorkshire	Yorkshire, Oxon, Weymouth.	Havre.
	vittata, Phil.			Yorkshire.	
	lineata		Yorkshire, Dundry, Normandy.		
	Planorbis ? euomphalus ?		? Bath.		
	Ampullaria gigas, Von Stromb.			Kahleberg near Echte.	
	Helicina polita	Cropredy.			
	compressa	Leicestershire.			
	expansa	Lyme.			
	solarioides	Ditto.			
	Nerita sinuosa				Portland.
	lævigata		Dundry.		
	minuta		Ancliff.		
	costata		Dundry, Yorkshire.		
	Rostellaria composita		Scarborough, Brora, Wiltshire.		
	bispinosa, Phil.			Scarborough.	
	trifida, Bean			Ditto.	
	———, Phil.	Whitby coast.			
	Buccinum unilineatum		Ancliff.		
	Pterocerus oceani, Bt.		Alsace, Mantua		Havre, Haute Saone.
	Ponti, Bt.				Havre.
	Pelagi, Bt.				Ditto.
	Murex Haccanensis, Phil			Hackness, Yorkshire.	
	Dentalium giganteum, Phil.	Staithes, &c., Yorkshire.			
	cylindricum	Devonshire.			
	quadratum, Phil.		Scarborough.		
Cephalopoda.	Belemnites tubularis, Y. and B.	Whitby coast.			

Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
Cephalopoda	Belemnites elongatus, Mill	Lyme, Whitby.			
	aduncatus, Mill.	Lyme, Bath.			
	compressus, Phil.	Whitby coast.			
	longissimus, Mill.	Lyme, Bath.			
	pistilliformis, Bl.	Charmouth.			
	acutus, Bl.	Ditto.			
	penicillatus	Ditto.			
	brevis, Blain.	Alais.			
	apicicurvatus, Bl.	Ditto.			
	giganteus, Bl.	Amberg.			
	penicillatus, Bl.	Salins, Anduze.			
	bisulcatus, Bl.	Caen.			
	aalensis, Bl. Voltz.		Bopfingen, Baireuth.		
	conicus	Whitby.			
	sulcatus, Mill.	? South of France	Dundry	Malton.	
	ellipticus, Mill.		Dundry, Haute Saone.		
	abbreviatus, Mill.		Dundry, Yorkshire	Weymouth.	
	fusiformis		Stonesfield	Malton.	
	gracilis, Phil.			Scarborough.	
	trisulcatus, Bl.		North of France.		
	compressus, Bl.		Yorkshire coast, Gundershofen, &c.		
	dilatatus, Bl.	Baireuth	North of France. (Boblaye.)		
	canaliculatus, Schl.		Haute Saone	Haute Saone.	
	longus, Voltz.		Ditto.		
	ferruginosus, Voltz.		Swabia, Bavaria	Ditto.	
	semisulcatus, Mün.			? Böhringen, Mögglingen, Bahlingen	
	subclavatus, Voltz.		Gundershofen.		
	subdepressus, Voltz	Gundershofen.			
	subaduncatus, Voltz		Ditto.		
	breviformis, Voltz.		Ditto.		
	ventroplanus, Voltz	Befort, Gundershofen.			
	longisulcatus, Voltz		Ditto.		
	trifidus, Voltz		Ditto.		
	comprimatus, Voltz	Bahlingen.			
	tenuis, Mün.	Altdorf.			
	paxillosus, Schl.	Befort, Boll.			
	acuarius, Schl	Banz, Altdorf.			
	crassus, Voltz	Besançon.			
	tripartitus, Schl.	Altdorf.			
	semistriatus, Mün.				
	oxyconus, Hehl	Ditto, Banz, Boll.			
	elongatus	Lyme Regis.			
	incurvatus, Hehl.	Banz, Boll.			
	pyramidalis, Mün.	Banz		Staienberg.	
	rostratus, Hehl.	Ditto.			
	clavatus, Blain.	Lyme, Boll, Amberg, Banz.			
	teres, Stahl.	Gosbach, Würtemberg.			
	lævigatus, Zieten	Boll.			
	papillatus, Pheninng.	Ditto.			
	carinatus, Hehl	Ditto.			
	pygmæus, Zieten	Ditto.			
	unisulcatus, Hart.	Wurtemberg.			
	bisulcatus, Hart.	Boll.			
	quadrisulcatus, Hart.	Goppingen.			
	tricanaliculatus, Hart.	Stufenberg.			
	quadricanaliculatus, Hart.	Ditto.			
	quinquecanaliculatus, Hart	Göppingen.			
	pusillus, Mün.			Streitberg.	
	ceformis, Mün.			South of Germany.	
	umbilicatus, Bl.		Normandy.		
	gladius, Bl		Metzingen, Baireuth.		
	Blainvillii, Voltz		Swabia.		
	hastatus, Bl.		Baireuth, Banz, Metz.		
	semihastatus, Bl.		Baireuth.		
	quinquesulcatus, Bl.		Würtemberg.		
	grandis, Schüller		Stufenberg.		
	tumidus, Zieten		Ditto.		
	acuminatus, Schül.		Ditto.		
	subhastatus, Zieten		Ditto.		
	bipartitus, Hart.		Grübingen.		
	unicanaliculatus, Hart.		Donzdorf.		
	bicanaliculatus, Hart.		Gunzboren.		

Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	Upper Oolite.
Cephalopoda.	Nautilus annularis, Phil.	Whitby.			
	truncatus	Keynsham.			
	intermedius	Ditto, Lyme, Würtemberg, Alsace.			
	striatus	Lyme.			
	astacoides, Y. and B.	Whitby.			
	lineatus	Yorkshire, Bath	Yorkshire, Bath, Dundry.		
	obesus		Gloucestersh. Normandy.		
	sinuatus		Yeovil.		
	excavatus		Dorsetshire.		
	hexagonus			Yorkshire, Oxon.	
	angulosus, D'Orb.				Isle d'Aix.
	polygonalis		Ditto.		
	reticulatus	France.			

Ammonites.

Group.	Name.	British Localities. In Lias.	British Localities. In Oolite.	Foreign Localities. In Lias.	Foreign Localities. In Oolite.
Arietes, *viz*	Bucklandi	Bath, Whitby		Near Donaueschingen, Phil.	
	Conybeari	Ditto, ditto		Meurthe, near Donaueschingen, Phil.	
	Turneri	Whitby, Watchet.			
	Brookii	Lyme.			
	Smithii	Near Yeovil.			
	rotiformis	Near Bath.			
	Kridion, Rein.			Stuttgart.	
	obtusus	Yorkshire.			
	stellaris	Lyme.			
	multicostatus	Bath.			
	Walcottii	Whitby, Bath, Lyme.		North and South of France, Boll, Befort, Achelberg.	
	redearensis	Redcar, Yorkshire.			
Falciferi, &c.	Strangwaysii		Yeovil, *l.* Gloucestersh. *l.*	Gundershofen, Altdorf, Boll	Haute Saone, *l.*
	elegans	Yorkshire	Yeovil, *l.* Bath, *l.*	Boll, Normandy.	
	striatulus	Whitby		Bas Rhin	
	Mulgravius, Y. & B.	Yorkshire		Boll.	
	Lythensis, Y and B.	Ditto		Meurthe.	
	ovatus, Y. and B.	Ditto.			
	impendens, Y. and B.	Ditto.			
	exaratus, Y. and B.	Ditto.			
	planorbiformis, Mun			Bavaria.	
	canaliculatus, Mun.				Wösshaau, *m* Fürstenberg, *m.* Bahlingen, *m.*
	Murchisonæ		Bridport, Hebrides		Gundershofen, Wisgoldingen, Goslar.
	subradiatus		Bath.		
	læviusculus	Whitby coast	Dundry.		
	depressus, Bon.		Ditto, Bayeux.		
	fonticola, Murch.				Thurnau, Bamberg, Dives, Besançon Haute Saone, *m.*
	Deluci, Bgt. / binus, Sow.				Neuhausen, *m.*
	comensis, V. Buch.				Ditto, *m.*
	falcifer		Dundry, Ilminster, Würtemberg		Normandy, South of France, Würtemb.
	solaris, Phil.		Scarborough calc grit.		
	obliquatus, Y. and B.	Whitby.			
	Boulbiensis, Y. & B.	Ditto.			
	jugosus		Ilminster, *l.*		
Amalthoi	Greenovii	Lyme			Dünkesbühl, *l.*
	Loscombii	Ditto.			
	Stokesii		Bridport	Normandy. South of France, Würtemberg.	
	vittatus, Phil.	Whitby.			
	acutus			Normandy	Haute Saone, Wasseralfingen.
	sigmifer, Phil. / costulatus, Rein.	Ditto		Wasseralfingen.	
	colubratus, Montf			Waichingen, Dünkesbühl.	
	Johnstonii	Watchet.			
	Clevelandicus	Whitby coast.			
	crenularis, Phil.	Whitby.			
	heterophyllus	Whitby coast.			
	lenticularis, Phil.	Lyme Regis.			
	Hawkerensis, Y. and B. / nodulosus, Schl.	Whitby coast		Würtemberg.	

Group.	Name.	British Localities. In Lias.	British Localities. In Oolite.	Foreign Localities. In Lias.	Foreign Localities. In Oolite.
Amalthei	alternans, V. Buch.				From Bamberg to Swisserland, *m.*
	vertebralis		Yorkshire, Oxon, *m.* Somersetshire, *l.*		Haute Saone, *m.*
	quadratus				Normandy, *l.*
	excavatus		Oxford, *m.* Walton, *m.*		Normandy, *m.* Aarau, *l.* Altdorf, *l.*
	Lamberti		Portland, *u.*		Rochelle, *u.* Aarau, *m.* Bamberg, *m.* Elligserbrink, *m.*
	omphaloides		Ditto, *u.* Hebrides, *m.*		Normandy, *m.*
	cristatus		Weymouth, *u.*		Haute Saone, *m.* Gottenberg, *m.* Streitberg, *m.*
	pustulatus, Rein.				Thurnau, *m.* Coburg, *m.*
	funiferus, Phil.		Yorkshire, *m.*		
	discus	Lyme	Bedford, *l.*		Spaichingen, *l.*
	nodosus		Scarborough.		
	flexicostatus, Phil.		Ditto, *m.*		
Capricorni	planicostatus	Marston, Lyme		Harz, Amberg, Altdorf.	
	maculatus	Whitby coast		Bahlingen, Heligoland.	
	angulatus, Schl. anguliferus, Phil.	Ditto		Neckar, Thailfingen, Willerson, near Schippenstadt.	
	N.S.			Gundershofen.	
	scutatus, V. Buch			Banz, Göppingen.	
	natrix, Schl.			Bahlingen, Brunsrode, Altdorf.	
	fimbriatus	Whitby		Normandy, Mende, Conflans, Rennerstorf, Aristorf, Boll, Bahlingen, Banz, &c.	
	balteatus, Phil.	Ditto.			
	Jamesoni	Yorkshire, Hebrides.			
	brevispina	Whitby, Hebrides.			
	gagateus, Y. and B.	Whitby coast.			
Planulati	annulatus	Whitby, &c.		Solenre, Lyons, Mont d'Or, Würtemberg.	
	communis	Ditto.			
	angulatus	Ditto.			
	crassus, Y. and B.	Whitby, Himalayan mtn.			
	biplex	Ross, Cromarty, Lincolnshire			Randen, *m.* Rathshausen, *m.* Streitberg, *m.* Haute Saone, *m.* Normandy, *l.*
	Parkinsoni	Bath	Yeovil, *l.*		The Swiss Jura, *l.* Wasseralfingen *l.* Wisgoldingen, Bopfingen.
	funicularis, V. Buch	Vic.			
	triplicatus		Malton, *m.*, Portland, *u.*		Randen, *m*, Swabia, *m.*, Normandy, *l.*
	plicatilis		Malton, *m*, Oxford, *m.*		Haute Saone, Percy le grand Champel, Randen, *m.*
	polyplocus, Rein.				German Jura, *m* ?
	polygyratus, Rein.				Donzdorf, Randen, *m.* ?
	comptus, Rein.				Donzdorf, Amberg.
	giganteus		Portland, *u.*		Isle d'Aix, *u.* Synbirsk, on the Wolga
	trifidus		Oxford, *m.*		
	bifurcatus, Schl.				Rathshausen, *m.*, Lochenberg, *m.*, Coburg, *m.*, Bareuth, *m.*
	trifurcatus, Rein.				Würtemberg.
	plicomphalus, mutabilis		Yorkshire, *u.* Lincolnshire, *u.*		Normandy.
	multiradiatus, Reng.				Willibaldsburg near Eichstedt.
	Kœnigii	? Lyme	Wiltshire, *m.*, Yorkshire, *m.*		Hohenzollern *l.* Gammelhausen, *l.*
	Brownii		Dundry, *l.*		
	longidorsalis, V. Buch.				Croizeville, *m*, Caen, *l.*
	mutabilis, Phil		Scarborough, *m.*		
	planorbis	Watchet.			
	nitescens, Y. and B.	Whitby.			
	arcigerens, Phil.	Ditto, Cheltenham.			
	erugatus, Bean.	Whitby, Cave, &c.		Coregna, De la Beche.*	

* From the same locality Mr. De la Beche figures A. cylindricus, stella, Phillipsii, biformis, Listeri ? coregnensis, Guidoni, articulatus, discretus, ventricosus, comptus, catenatus, trapezoidalis. *Man. of Geol.* p. 319.

Group.	Name.	British Localities. In Lias.	British Localities. In Oolite.	Foreign Localities. In Lias.	Foreign Localities. In Oolite.
Dorsati	armatus	Whitby, Bath			Normandy, m., Haute Saone, m.
	Davæi	Lyme		Pouilly near Autun.	
	fibulatus	Whitby.			
	subarmatus	Ditto.			
	Brodiæi		Portland, u.		
Coronarii	crenatus, Rein.				Germany, m.
	Humphresianus		Dundry, l.	South of France.	
	Bollensis, Zieten.			Boll.	
	Bechii	Lyme.		Rottweil, Bahlingen.	
	Blagdeni		Scarborough, l. Sherborne, l., Dundry, l.		Spaiklingen, l., Metzingen, l., Normandy, l.
	Brakenridgii		Dundry, l.		Normandy, l., Germany, m, Gammelshausen, m.
	Vernoni, Bean		Scarborough, m. Brora, m.		
	contractus		Dundry, l.		Normandy, l.
	dubius, Schl.				Gammelshausen, l. Thurnau, l.
	Gowerianus		Scarborough, m. Cromarty, m.		
	Birchii	Ditto			Mezieres.
Macrocephali	tumidus, Rein.				Aarau, m., Coburg, m. Vaches Noires, m.
	inflatus, Rein. Sutherlandiæ, Sow.		Brora, m., Scarborough, m.		Randen, m., Thurnau, m. Staffelberg, m.
	sublævis		Wiltshire, m., Yorkshire, m.		Near Randen, m, near Villingen, m.
	modiolaris, Smith.		Bath, l.		
	Herveyi		Wiltshire, l., Lincolnshire, l., Yorkshire, l.		Wurtemberg, l., Bavaria, l., Swisserland, l.
	terebratus, Phil.		Yorkshire, l.		
	Banksii		Sherborne, l.		Basle, l.
	Brochii		Dundry, l.		Haute Saone, l.
	Gervillii				Normandy, l.
	Brongniarti		Yeovil, l.		Ditto, l.
	subcarinatus, Y. & B.	Whitby.			
Armati	perarmatus		Yorkshire, l., Oxford, l.		Near Banz, m., near Nürnberg, m, Randen, m., Normandy, m.
	longispinus.				
	catena		Berkshire, m.		
	biarmatus, V. Zieten.				
	athleta, Phil.		Yorkshire, m.		
	Ziphus, Hehl.				
	Williamsoni, Phil.		Ditto, m.		(Geschiebe bei Berlin.)
	Bakeriæ				Normandy, m.
	bifrons, Phil.		Scarborough, m.		
	lævigatus.	Lyme Regis.			
	Birchii	Lyme			Göppingen.
Dentati	Jason, Rein. Calloviensis, Sow.				Lafollepetit, Gammelshausen, l., Belosetzk near Orenburg.
	Gulielmi, Sow		Wiltshire, m., Yorkshire, m.		Elligserbrink, m.
	hylas, Rein.				
	Duncani		Scarborough, m. St. Neot's, m.		Normandy, m., Haute Saone, m.
Ornati	A. Pollux, Rein.				Normandy, m., Goslar, m., Thurnau, m.
	gemmatus, Phil.		Scarborough, m.		
	spinosus, Sow.		Weymouth, m.		
	castor, Rein.				
	pustulatus, Rein.				Coburg, Thurnau.
Flexuosi.	flexuosus, Mün.				Along the whole German Jura, m.
	asper				Neufchatel, n.
	oculatus, Phil.		Yorkshire, m.		

Unarranged Foreign Species.

Name.	British Localities. In Lias.	British Localities. In Oolite.	Foreign Localities. In Lias.	Foreign Localities. In Oolite.
A. granulatus, Bt.				Coburg, m.
Reinechii, Holl.				Ditto.
gigas, Zicten.				
Sowerbii, Moll.		Dundry, l.		
Deslongchampii, Bobl.				North of France, l.
vulgaris, Bobl.				Ditto.
corrugatus, S.		Dundry.		Ditto.

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Family.	Name.	British Localities. In Lias.	British Localities. In Oolites.	Foreign Localities. In Lias.	Foreign Localities. In Oolites.
Cephalopoda	A. interruptus, Schl.				Haute Saone, *m.*
	decoratus, Ziet.				Guttenberg, *l.*
	bipartitus, Ziet.				Ditto.
	bispinosus, Ziet				Wasseralfingen, *l*
	Scaphites refractus, Rein.				Gammelshausen, *l.*
	Yoannii				Basses Alpes.
	Hamites annulatus, Desh.				France.
	——— Mün.				Rabenstein, Thurnau.
	Turrites Babili, Bt.				North of France.
	Onychoteuthis angusta, Mün.				Solenhofen.
	Loligo priscus, Rüppell.				Ditto.
	antiqua, Mün.				Ditto.
	Sepia hastæformis, Rüpp.				Ditto.
	———		Lyme Regis.		
	Rhyncolites.		Lyme, Bath.		

ANNULOSA.

Name.	Lias.	Lower Oolite.	Middle Oolite.
Vermicularia concinna, Phil.		Yorkshire coast.	
compressa, Y. and B. / ovata			Scarborough.
nodus		Westow, Yorkshire.	
Serpula capitata, Phil.	R. Hood's Bay, Yorkshire.		
deplexa, Bean.		Yorkshire coast.	
squamosa, Phil.			Ditto.
intestinalis			Ditto.
quadrata		Scarborough, Bath.	
lacerata, Phil.			Ditto.
triangulata		Bradford, Wilts.	
tetragona		Ditto, ditto.	
runcinata			Shotover, Oxon.

N. B. Goldfuss (*Petrefactenkunde*) has figured and described forty-two species of serpula from the oolitic system of Germany and France. According to Von Dechen their Geological relations are as under:—

From the Lias.

Serpula tricristata, Goldf.	Banz.
quinquecristata, Mün.	Ditto.
circinalis, Mün.	Ditto.
quinquesulcata, Mün.	Baireuth.
complanata	Ditto.

From the Lower Oolites.

limax, G.	Baireuth.
lituiformis, Mün.	Ditto.
capitata, G.	Streitberg.
limata, Mün.	Ditto.
plicatilis, Mün.	Græfenberg.
spirolinites, Mün.	Streitberg.
tricarinata, G.	Rabenstein.
pentagona, G.	Streitberg.
quadrilatera, G.	Rabenstein.
quadristriata, G.	Birrach. (Burgundy.)
canaliculata, Mün.	Streitberg.
volubilis, Mün.	Rabenstein.
cingulata, Mün.	Streitberg.
substriata, Mün.	Rabenstein.
flaccida, G.	Rabenstein, Alsace.
Serpula filaria, G.	Græfenberg
socialis, G.	Bavaria, Swabia.

From the Upper Oolites.

grandis	Heidenheim, (also in lower oolites.)
conformis, G.	Buxweiler.
delphinula, G.	Streitberg, Thurnau.
gibbosa, G.	Muggendorf.
nodulosa, G.	Streitberg.
quinquangularis, G.	Normandy.
prolifera, G.	Streitberg.
planorbiformis, M.	Ditto, Thurnau.
trochleata, M.	Streitberg.
macrocephala, M.	Thurnau.
heliciformis, G.	Neufchatel, Haute Rive.
quadristriata, G.	Amberg.
convoluta, M.	Streitberg, Baireuth, &c.
Deshayesii, M.	Streitberg.
spiralis, M.	Muggend. Nutth. Heidenh.
flagellum, M.	Streitberg.
gordialis, Schl.	Nutth. Heidenh. Buxweiler.
intercepta, G.	Streitberg, Culmbach.
ilium, G.	Streitberg, Thurnau.

CRUSTACEA.

Name	Lias.	Lower Oolite.	Middle Oolite
Astacus longimanus, Kœnig.	Lyme.		
rostratus, Phil.		Scarborough.	Scarborough, Malton
mitis, Phil. M S.		Ditto.	
scabrosus, Phil. MS.			Malton.
New genus? ——— Phil. MS.			Scarborough.
Cancer			Malton.

The following are from Solenhofen:—

Astacus spinimanus, Germ.
leptodactylus, Germ.
modestiformis, Holl.
minutus, Holl.
fuciformis, Holl.
Pagurus mysticus, Germ.
Scyllarus dubius, Holl.
Eryon Cuvieri, Desm.

Eryon Schlottheimii, Holl.
acutus, Germ.
muticus, Germ.
spinimanus, Germ.
Mecochyrus locusta.
Palæmon spinipes, Dem.
squillarius, Dem.
Walchii, Holl.

INSECTS.

Traces of Insects occur at Stonesfield, and very fine specimens of libellulidæ and hymenoptera at Solenhofen.

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Reptilia.

This list is principally taken from Von Meyer's *Palæologica* and De la Beche's *Manual.*

Family of Saurians.	
Pterodactylus macronyx, Buckl.	In lias, Lyme Regis.
longirostris, Cuv.	In slaty limestone, Eichstadt.
brevirostris, Cuv.	Ditto, ditto.
grandis, Cuv.	Ditto, Solenhofen.
Bucklandi, Von Meyer	Lower oolite, Stonesfield.
crassirostris, Goldf.	In slaty limestone, Solenhofen.
medius, Mün.	In oolite, Manheim.
Munsteri, Goldf.	Ditto.
Crocodilus cylindrirostris, Cuv.	In lias, Altdorf.
priscus, Soëm.	In oolite, Manheim.
Altdorfensis, Cuv.	In lias, Altdorf; in Kimmeridge clay, Honfleur, Havre.
Geoffroyi, Von Meyer	In Kimmeridge clay, Honfleur, Havre.
Of Mans, Cuv.	In oolite ?
undetermined species	In lias of Yorkshire, Lyme Regis: in cornbrash, Northamptonshire, Stonesfield slate, and coralline oolite of Yorkshire.
Teleosaurus Cadomensis, G. St. H.	In oolite, Caen.
Geosaurus Bollensis, Jæg.	In lias, Boll.
Soëmmeringii	In slaty limestone, Solenhofen.
Megalosaurus Bucklandi	In Stonesfield slate.
———	In oolite, Normandy.
Lacerta Neptunia, Goldf.	Manheim.
Iguanodon Mantelli, Von Meyer	In the Wealden formation, Tilgate.
Hylæosaurus ———, Mantell	Ditto, ditto.
Pleurosaurus, Goldf., Von Meyer	In slaty limestone, Solenhofen.
Rhacheosaurus gracilis, Von Meyer	Ditto, ditto.
Family Enaliosauri, Conyb.	
Ichthyosaurus communis, De la B. and C.	In lias, Lyme, Yorkshire, Boll, &c.
tenuirostris, De la B. and C.	Ditto, ditto.
platyodon, De la B. and C.	Ditto, Lyme, Boll.
intermedius, De la B. and C.	Ditto, ditto.
grandipes, Sharpe	In lias.
coniformis, Haslan	Ditto, Bath.
other species	In the lias and Kimmeridge clay.
Plesiosaurus dolichodeirus, Conyb.	In lias, Dorsetshire, &c.
recentior, Conyb.	In Kimmeridge clay, England, Normandy.
carinatus, Conyb.	In oolite, Boulogne.
pentagonus, Cuv.	Ditto, Ballow, Chaufour.
trigonus ? Cuv.	Ditto, Calvados.
macrocephalus, Conyb.	In lias, Lyme Regis.
new species, Hawkins	Ditto, Somersetshire.
Family Chelonia.	
Emys, Mantell	In the Wealden, Sussex, Jura, Solenhofen.
Chelonia of Glaris, Cuv.	In lias, Plattenburg in Glaris.
others	Stonesfield, Sussex, Solenhofen.

Mammalia.

Didelphis Bucklandi, Broderip	In Stonesfield slate. Four specimens of the lower jaw exist. They are in the cabinets of Dr. Buckland, Mr. W. J. Broderip, M. C. Prevost, and the Yorkshire Philosophical Society. The latter specimen was obtained from Stonesfield by Mr. Platt, and by him transferre d to Sir Christopher Sykes, Bart., in whose collection, now the property of the Rev. C. Sykes, it was discovered by the writer of these pages.

Pisces.

Name.	British Localities. In Lias.	British Localities. In Oolites.	Foreign Localities. In Lias.	Foreign Localities. In Oolites.
Uræus gracilis, Agassiz			Würtemberg.	
Sauropsis latus, Ag.			Ditto.	
Ptycholepis Bollensis, Ag.			Boll.	
Semionotus leptocephalus, Ag.			Zell, near Boll.	
Lepidotes gigas, Ag.			Ohmdern, near Boll.	
frondosus, Ag.			Zell.	
ornatus, Ag.			Würtemberg.	
Leptolepis Bronnii, Ag.			Near Donaueschingen.	
Jægeri, Ag			Zell.	
longus, Ag.			Ditto.	
Tetragonolepis heteroderma, Ag.			Ditto.	
semicinctus, Bronn.			?	
pholidotus, Ag.			Ditto.	
Traillii, Ag.	England		South of Germany ?	
altivelis Ag.			Ditto ?	
Dapedium politum, De la Beche	Lyme Regis, &c.			
Fish teeth and palates	Ditto, Bath, &c.	Yorkshire, *m.* Bath, *l.* Oxfordshire, *l.*		
Ichthyocopros	Lyme			Normandy, *t.*
Undescribed fishes	Barrow, Whitby	Portland, *u.* &c.		

The following are from the metamorphic lias of Glarus formerly called greywacke slate.

Zeus Regleysianus, Bl.
platissa, Bl.
spinosus, Bl.
Palæorhynchum Glarisianum.
Clupea Scheuchzeri, Bl.
elongata, Bl.
megaptera, Bl.
Anenchelum Glarisianum, Bl.

The following are from the lithographic limestone of Solenhofen, Pappenheim, Manheim, and Eichstedt.

Clupra encrasicholoides, Germ.
dubia, Bl.
Knorrii, Bl.
Salmonea, Bl.
Davidei, Bl.
Pæcilea dubia, Bl. .... Anspach ?
Atherina Bavarica, Germ.
Esox avirostris, Germ.
acutirostris, Bl.
Stromateus hexagonus, Germ.
Ichthyolithus esociformis, Germ.
luciiformis, Germ.

And species supposed to belong to cyprinus ? perca ? squalus, zeus ? chætodon ? sparus.

General Summary.

Plants marine	4	These occur in the limestones.
terrestrial cryptogamous.	39	These are found in the sandstones and coal shales. The coal is principally composed of equiseta.
gymnospermous ...	33	
monocotyledonous,&c.	4	

Polyparia fibrous........	75	Conchifera brachiopoda..	61
corticiferous and celluliferous .	44	Mollusca gasteropoda ...	114
		cephalopoda ...	273
lamelliferous ...	59	Annulosa.	55
Radiaria crinoidea	31	Crustacea	22
stellerida	7	Insects	
echinida	47	Fishes	40
Conchifera plagymyona .	189	Reptiles	40
mesomyona	134	Mammalia	1

Total number of species 1272

It is impossible to close this extensive catalogue of the plants and animal remains of the oolitic period without acknowledging the great value of Mr. De la Beche's laborious investigations in this yet inexhausted field. In the German translation of his *Manual of Geology*, for which we are indebted to M. Von Dechen, are many important additions and improvements.

Cretaceous System.

Mineral character.

That a peculiar type, of mineralogical character, belongs to each system of formations, must have been sufficiently evident through the whole course of our investigation. The gneiss and mica slate system, the clay slate system, the limestones of the carboniferous system, the coloured marls and magnesian limestones of the saliferous system, the oolites, are all resting points for the mind, and amidst a multitude of shades and gradations, strongly impress upon us the distinctive features of the several periods of time at which these so different rocks were in a predominant degree produced.

Mineral characters alone, when rightly used, are in many instances sufficient to determine the Geological relations of even distant regions; and when conjoined with the evidence of organic remains, and controlled by careful survey of the strata above and below, they form a secure groundwork for topographical Geology.

The cretaceous system is equally definite as any of the others with respect to the distinctness of its prevailing mineral ingredients, and not less characteristically marked by peculiar marine exuviæ. Chalk and green sands are terms understood by all the Geologists of Northern Europe; and even on the Southern side of the Alps their representatives may be recognised.

Surface of country.

Through England, the ranges of chalk hills form a geographical feature even more important than that of the oolites; for though in general not so elevated, they are less interrupted and more extensive, more uniform in composition, and therefore more identical in aspect. The chalk hills form the first great ridge which is to be crossed from the Eastern side of the Island, and nothing can be more remarkable or instructive than such a journey. On approaching these broad hills from the level or gently undulated plains of the Eastern Counties, or the clay vales of the oolite system, the country changes entirely. The streams run in smoothly sloping valleys, the hills rise with beautiful swells into a long waving outline, seldom broken by a tree, but often capped by an ancient tumulus. Arrived on the summit, we behold a mighty extent of broadly undulated land with abundance of depasturing cattle, but few habitations of men. A variety of plants, eminently characteristic of calcareous soil, force themselves on the attention; flints abound in the fields, chalk is cut through in the roads, the soil is thin, the herbage short, the surface dry, and we feel ourselves in a new physical region.

This impression is confirmed when we observe more carefully the numerous undulations upon the surface of the "wolds;" for all these may be traced into connection as so many ramifications of greater valleys, which themselves often unite, and pursue a considerable course without enclosing even the smallest rill, or showing even the mark of a watercourse. These *dry valleys* descend from their origin in regular slopes, and are clearly the work of water, operating with great force, and for some time, but in the present system of Nature the watery agent has wholly disappeared.

The rains are absorbed as fast as they fall upon this dry surface, and sink to considerable depths in the rock, where they are treasured up in reservoirs to supply the deep wells and the constant springs which issue at lower levels.

In a word, broad, swelling hills, smooth, winding, often dry valleys, and a bare dry, grassy, surface, are the general features of the chalky districts.

This character of surface belongs, as Dr. Lister remarked long ago, to the chalk wolds of Yorkshire, Lincolnshire, Norfolk, Suffolk, Berks, Wilts. Dorset, Hampshire, Surrey, Kent, and Sussex.

Groups of the system.

The cretaceous system forms properly but one formation. Supposing the whole to be present in a single section, we should have the following general series.

Chalk group.	*f.* Upper chalk, with abundance of flints in layers and nodules.
	e. Lower chalk, with fewer flints.
	d. Chalk marl, or malm.
Green sand group.	*c.* Upper green sand, malm rock, or firestone.
	b. Gault clay.
	a. Lower green sand or iron sand.

d and *c* are sometimes *undistinguishable*. The lower green sand generally forms a distinct ridge, which may even exceed the chalk in height.

The complete system here presented occurs in many parts of Kent, Sussex, and Hampshire, but generally in other parts of England the sections are modified, so as to present only partial assemblages of the beds, some-

times one, sometimes another being deficient; and with respect to the malm rock, great differences being observable. Thus, in Wiltshire, where Mr. Smith took the type of this formation, we have the upper green sand remarkably developed; the lower one and the gault are contracted.

Chalk upper } lower }	....	500 feet.
Chalk marl	....	100
c. Green, grey, and yellow sand	......	120
Gault	....	50
Lower green sand	....	30

Along the line of chalk hills from the valley of the Thames to Lynn, the upper green sand is almost lost in the chalk marl and gault; green grains being mixed with the former, and still more in the upper layers of the latter. In Bedfordshire, the chalk marl produces a bed of silicious, chalky stone, which may probably be analogous to the firestone of Mesterham in Surrey, which is determined to belong to the upper green sand series. Indeed, the sections along this part of the chalk range are very similar to those of Sussex and Kent.

In Lincolnshire we meet with a new feature, a band of red chalk; at the base of that, thick rock; under this no upper green sand, and generally no gault, but the chalk rests upon a thick series of greenish and ferruginous sands, with included beds of sandy limestone, full of fossils resembling those of the lower green sand of Kent. This country has been very badly represented in all our maps.

In Yorkshire, the cretaceous system consists of
Upper chalk.
Lower chalk and traces of chalk marl.
Red band of chalk.
Gault with green grains passing downwards into Kimmeridge clay, without the intervention of the lower green sand.

From several recent researches abroad it has been thought that the chalk group of England and France is imperfect in the upper terms, and that the well-known Maestricht beds, and the recently investigated Gosau beds, appear to soften the transition from the chalk to the true tertiary strata. If Mr. Webster's observation of a supercretaceous marl in the Isle of Wight belong to this era, analogous deposits are not *absolutely* wanting in England. We shall now trace the history of these several members of the green sand and chalk groups, beginning as usual with the lowest.

The lower green sand. (Syn. Iron sand. Shanklin sands, &c.)

In Lincolnshire, the lower green sand is a considerable mass of yellow, often very irony sand, forming, toward the West, poor heaths upon the Kimmeridge clay, exactly like those about Lynn, Ampthill, and Godstone. It contains a good deal of bad ochre, very similar to that of Shotover Hill, and lines of oxyde of iron like that of Ryegate. Beds of grey stone, blue within, flat-bedded, sandy, and full of fossils, lie in it, and afford excellent road materials. These are dug at Tealby, Market Stainton, Ludford, Cawkwell, Blustone Heath, Stainton in the Hole, &c. It has considerable resemblance to the Kentish rag, and contains exogyra sinuosa, pecten cinctus, plagiostomata, serpulæ, ammonites, alcyoniform bodies, small corals, and many other fossils; but echini and belemnites appear unknown in it. From these details it is evident that the stratum has all the most decided characters of lower green sand. It is exposed by denudations in the chalk, and also ranges on the West of the wolds for a great length by Rasen, Lessington, Linwood, &c. to Louth. The whole thickness is probably 100 feet. These notices are partly derived from personal observation in 1821, but principally from a special visit to the district in 1833 with two friends, Messrs. Dikes and Lee of Hull, who have fully explored it.

As usual in coloured sands, this stratum often contains veins of perfectly white sand. At Lynn this has been found of value for the glass-houses. In Cambridgeshire and through Huntingdonshire, the iron sand forms a narrow course of low hills, but through Bedfordshire and Buckinghamshire it takes a commanding station, forming heathy ridges from Potton to Woburn, and through Buckinghamshire and Oxfordshire, capping Brickhill and Brill Hills, Shotover Hill, Cumnor Hurst, and Faringdon Clump. In Wiltshire, Spy Park, Bowood, Seend Hill, are capped by these beds, but they are supposed to thin out to the South, and to be lost, until in Blackdown they are probably associated with the upper green sand. In the Isle of Purbeck and the Isle of Wight it is an important rock, and, as observed before, encircles the whole of the Wealden formation of Kent and Sussex.

Through the whole of its range from Cambridgeshire into Wiltshire it is a highly ferruginous sand, with spheroidal or merely irregular concretions of oxyde of iron, frequently enclosing a coarse brown ochre. At Shotover, the fine yellow ochre forms two irregular beds, separated by a thin parting of clay. Fuller's earth also occurs in it in layers in Bedfordshire, especially at Woburn. Grains of green sand abound in some layers of these beds in Bedfordshire and Buckinghamshire, and constitute it a real green sand Chert layers also are formed in it, and many of the beds assume the aspect of coarse conglomerate, used by the ancient Britons for the making of quern stones or carstones, whence Mr. Smith gave this name as a synonyme of the iron sand. Fossil wood is frequent in these beds. In Bedfordshire its thickness may be stated at 100 feet; in Wiltshire Mr. Lonsdale finds it 30.

In the Isle of Purbeck, the iron sand consists of many beds of quartzose conglomerate, and of coarse and fine grained sandstones, containing beds of wood coal. In the Isle of Wight, dark red ferruginous sandstones in the upper part, and alternations of red and yellow ferruginous sands and clays in the lower part, form the substance of all the Southern half of the Island, and contribute much to the beauty of the scenery of the Undercliff.

In its long course around the Wealds of Kent and Sussex, the lower green sand presents, with the general characters noticed above, some local peculiarities of interest. In Leith Hill, its extended plateau makes a commanding feature, and shows a great thickness of brown sands, with abundance of chert, with confluent grains passing into chalcedony, and some alcyonites like those of the Isle of Wight.

The importance of the lower green sand as a geographical feature diminishes as it proceeds round the South side of the Weald, but the Northern range is generally elevated and remarkably continuous by Ryegate, Nutfield, and Maidstone to Hythe and Folkstone. At Ryegate it is almost exactly like the ferruginous rock of Woburn; at Nutfield it produces beds of fuller's earth; from Maidstone to Hythe and Folkstone the sands are in general remarkably, and even excessively,

rich in green grains and nodules, and contain beds of whitish limestone, sometimes chalky and often cherty, with green grains, considerably rich in ammonites, trochi, cardia, pectens, lutrariæ, exogyræ, echinites, and other fossils. These beds may be generally called Kentish rag. Some of them are of a dark grey colour, very hard, full of green grains, and rich in many fossils, some of which are usually found in the upper green sand. The cherty beds of Leith Hill and Haslemere are probably the representatives of these calcareo-silicious layers.

Some of the beds of lower green sand about Folkstone are excessively coarse in the grain, and absolutely crammed with green grains and nodules. The large species of exogyra is very frequent, and appears characteristic. The blue marl or gault rests immediately on the sandy beds.

The gault or golt. (Syn. Blue Marl of Tetsworth and Folkstone, Micaceous Brick-earth, Smith.)

The gault or golt is an argillaceous member of the green sand group, of great interest to the Conchologist, since in Kent, Surrey, Sussex, Wiltshire, Cambridgeshire, and Yorkshire, it yields a most rich supply of molluscous remains, many of them minute and of the greatest beauty. It accompanies the lower green sand around the whole district of the Weald, separates the upper and lower green sand in the Isles of Wight and Purbeck, and follows with the same relations the range of the green iron sand through Wilts and Berks, Buckinghamshire and Bedfordshire, and Cambridgeshire, and appears in Yorkshire without either upper or lower green sands immediately below the chalk. Its average thickness may be fairly estimated at 100 feet, and it universally forms a characteristic narrow valley under the chalk. No remarkable peculiarity of mineralogical aspect or chemical composition distinguishes the gault, except a general tendency to admit green grains into its more sandy portions. It produces a capital brick earth fit for white bricks, in the midland Counties. It is often of a very dark blue, but sometimes of a light grey colour. Near Folkstone it contains in the lower part a remarkable layer of small, irregular, ironstone nodules, every one of which is formed round an ammonite. A similar layer contains similar ammonites at Steppingley Park, Bedfordshire. At Specton in Yorkshire oval nodules of similar nature generally enclose small specimens of astacus. Small belemnites, hamites, ammonites, nuculæ, striated terebratulæ, serpulæ, &c. abound in the gault, and serve admirably to complete the catalogues of fossils of the cretaceous system.

The upper green sand

The upper green sand was first examined in Wiltshire, where it consists of green, grey, and irony sands, immediately subjacent to the chalk, and affording passages for the collected water of that thick deposit downward to the gault. The green grains there assumed to be characteristic of these strata are now known to occur in older sands, (in calcareous grit, for instance,) and in much more recent beds, (as above the chalk frequently,) yet still the greenness of the sands immediately below chalk is a curious general fact. They are, however, quite as often grey or even whitish, with a remarkable tendency in the grains to coalesce into meagre sandstone, sandy chert, and at length semitransparent and chalcedonic chert. These effects are particularly to be observed among specimens of the sponges, and so called alcyonia, which abound in the green sand group. It is easy to understand how so variable a mass of sands placed immediately below the chalk, and clearly in many places (as at Havre) graduating into that calcareous rock, should in several instances become so cretaceous as to be hardly distinguishable from the chalk itself. This happens in Bedfordshire, where the Tattenhoe stone appears to be the representative of the upper green sand, in Surrey at Merstham, in Dorsetshire at Beer. Round the Weald of Surrey and Sussex, the malm rock, which is certainly coeval with the Wiltshire green sand, (Murchison,) and also with the Merstham firestone, occasionally shows many green grains, and at Beechy Head (Mantell) changes to nearly the ordinary type of the green sand of Wiltshire. From these considerations we are fully justified in regarding the upper green sand as intimately connected with the lower commonly argillaceous part of the chalk, just as the calcareous grit is with the coralline oolite, and the calciferous sand with the inferior oolite. In particular places, mechanical causes gave a predominance to its sandy character, and in others the abundance of organic exuviæ impressed it with a particular zoological type. This mode of viewing it exactly accords with its general character through France, where it is associated with the lower argillaceous chalk under the title of *glauconie crayeuse*. According to this classification, the upper green sand or firestone beds form a nearly continuous base for the chalk from Lynn to Dorsetshire, and round the whole of the Weald of Kent and Sussex, yielding organic remains at intervals.

Chalk marl.

Chalk marl may be viewed as the next step in the gradation of changes by which we are conducted from the green sand system to the true cretaceous type. It is, in fact, an argillaceous chalk, holding variable quantities of clay and sand, superimposed upon the green sand or malm rock, and gradually changing upwards to the lower chalk. It is, perhaps, observable on the Western slopes of the Yorkshire wolds above the red chalk, but is distinctly traceable below nearly the whole range of the chalk hills from Lynn to Dorsetshire, and round the whole of the Weald, every where closely associated with, and indeed hardly separable from, the malm rock or firestone, and often enclosing, as near Woburn and Folkstone, green grains and fossils of the true upper green sand.

Were it not that all such classifications are arbitrary, and only locally exact or valuable, we might conveniently group together the upper green sand and chalk marl divisions, and thus rank together the greatest part of the lower fossiliferous beds of the chalk, which, occasionally argillaceous, stony, or sandy, appear very generally interposed between the true chalk and the continuous lower green sand.

Lower chalk.

In England, generally, the lower half of the thick mass of chalk is harder, more jointed, and less divided by layers of flint nodules than the upper part. It is often of a greyer colour, and, to a certain extent, distinguishable by a different suite of organic remains. In particular, it appears to contain very few of the stellerida, crinoidea, or echinida, not so many belemnites or terebratulæ, but, on the contrary, yields more ammonites, some hamites, trochites, and other fossils approaching to those of the green sand group below. But the mineralogical character of the lower part of the chalk is liable to great variations. In Yorkshire, three-fourths of the whole mass are hard, and the lower portions are as much traversed by layers of flint nodules, at pretty regular distances, as the upper parts. In the Dover cliffs, beds of soft cretaceous marl divide the chalk without flints into two portions, the upper one yellowish, hard, and containing numerous thin beds of organic remains, the lower one whiter, softer, often gritty at the top, en-

closing masses of pyrites, but few organic remains. (W. Phillips, in *Geology of England and Wales*.)

The upper chalk is usually recognised in England by its whiteness, softness, numerous layers of flints at intervals of four to six feet, and abundance of zoophytic remains. Sponges of many kinds, small lamelliferous corals, millepores, crinoidea, stellerida, echinida of very remarkable form, large inocerami, belemnites, and abundance of terebratulæ are the most frequent of its numerous fossils. The layers of flint nodules are exceedingly interesting, and throw light upon the mode of formation of the chalk. They are always found in the planes of stratification, generally irregular in figure, black or grey within, with traces of spongiferous bodies, shells, echini, or other organic bodies. The external crust is usually white and silicious. The sponges also are often quite white and silicious, and lodged in a cavity, left by the decay of part of their substance. The crusts of echini are usually, even when enveloped in flint, converted to calcareous spar, and belemnites retain their original radiated structure. Occasionally, as at Sudbury, the flint occurs in thin layers parallel to the stratification.

It seems probable that in the formation of the chalk from the decomposition of the sea-water then holding lime and silica in solution, the carbonate of lime and silica fell to the bottom together, in quantities sufficient on each occasion to constitute a *bed* of chalk and flint, and that the latter substance was especially attracted by the organic remains then lying on or beneath the beds, so as to collect round the sponges, echini, &c., exactly as the oolitic matter has been collected round shells, the lias limestone round ammonites, the carbonate of iron round ferns, &c. Analogous cases occur in the spongiferous cherts of the Portland oolite and coralline oolite, and we might perhaps venture to extend the same mode of reasoning to the case of chert nodules in carboniferous limestone, for these often (not so generally as in the case of flint) contain organic remains.

Pyrites is generally plentiful in the upper chalk, variously crystallized, and is not unfrequently associated with silica in the sponges which lie in chalk. It is in these cases generally decomposed into brown oxide of iron.

Flints are very often split or cracked in their native repositories, as if by contraction of the mass, and this sometimes, but less frequently, happens, when organic remains of a solid kind are enclosed in them. The most remarkable cases of this nature are described by Mr. Webster, in the dislocated upper strata of chalk in the Isle of Wight. All the flints in the layers which alternate with chalk, are found broken in every direction into pieces of every size, which remain in their relative places enclosed within the cell of chalk, and showing no other signs of fracture than a fine line, as in shivered glass. On being removed from their place the flints fall into many pieces. This singular fact seems connected with the disturbances of the chalk, and may, perhaps, be due to the violence of the tremour then impressed upon the mass, a tremour which might shiver elastic flint, (especially if, like a Rupert's drop, its particles had been previously in a state of tension,) but leave the chalk unaffected.

Mr. Webster's account of a bed of argillaceous chalk or marl in the Isle of Wight, above the chalk with flints, seems to be the only indication of a transition or gradation of deposits between the chalk and the tertiary beds yet clearly observed in England. The marl dug on the Sussex Downs, as well as that in Hertfordshire and Norfolk, may, perhaps, be related to it.

Range of the Cretaceous System out of England.

The principal range of the cretaceous rocks is included within the general boundaries of the European basin, and it is probably not at all less extensive than the oolitic system, though by the diffusion of tertiary rocks above it, its course in large tracts of country is wholly subterranean.

The cretaceous system of Ireland is in a depression, on the Western side of what is usually understood by the basin of Europe. It consists of chalk 200 or 300 feet thick, harder than is common in England, but with a similar though less extensive suite of organic remains, and rests on green sand, there called *mulatto*, with the usual characters of that group in England. Lias is found beneath at the Giant's Causeway. In Scotland, only a very dubious indication of the cretaceous system is afforded by the flints which rest upon primary rocks near Peterhead. Ireland.

Within the natural modern boundaries of the principal basin of European secondary strata, the primary rocks of Scotland, Cumberland, Wales, Cornwall, and Brittany, on the West; the Pyrenees, the Alps, and the Carpathians, on the South; Caucasus and Oural on the East; Finland and Scandinavia on the North; the cretaceous system, chalky, marly, or sandy, is very largely developed. The type of the formation may be taken in Southern England or Northern France indifferently. In the latter Country its extent on the surface is probably equal to the whole superficial area which it occupies elsewhere in Europe. It encircles with a broad belt the basin of Paris, and passes off on the North-Eastern side into Belgium, which whole Country it probably underlies, though the tertiary deposits conceal it, except along the sides of the Meuse. At Maestricht the upper beds of the cretaceous formation have, in many respects, mineralogical and organic, a remarkable analogy to the *calcaire grossier*, which is the lowest really marine tertiary rock in the vicinity. These beds, however, by their principal characters really belong to the cretaceous system, of which they may be considered the highest terms at present known. A little appearance of the chalk is observable North of the coal of Elberfeld, to which it is unconformed, as well as to that of Namur and Liege. The chalk system most probably underlies the whole region of Northern Germany, from the point last mentioned North of the oolite and lias of Westphalia. The green sand is remarkably well exhibited with characteristic fossils in the romantic tract of Saxony, North of the Erzgebirge, (there called *quadersandstein*,) as well as an upper calcareous portion supposed equivalent to the chalk and planerkalk. North of the Carpathians, both chalk and green sand occur in long ranges of hills, passing from Poland by Lemberg into Podolia and the South of Russia. It reaches the Dneister, and extends to the plains of Volhynia. It forms considerable eminences around Grodno in Lithuania. "Further South, in the plains of Moldavia, Podolia, and Bessarabia, it appears only in detached portions. Chalk is found on the Southern side of the granitic Steppe in the Crimea, and on the borders of the Sea of Azof, between the Berda and the Don. In the Country of the Don Cossacks, in the Governments of Woronack, Koursk, and Toula, it

appears in hills and on the banks of rivers, and probably constitutes the base of that great and fertile plain." (Pusch, quoted by De la Beche, *Manual of Geology.*)

In Pomerania and Mecklenburg, and the Island of Rugen, cliffs of chalk occur with the usual fossils of England, and in Sweden it rests upon rocks of gneiss and greywacke, and only in one instance, at Limhamm in Scania, upon rocks of the oolitic era. In the North of Germany it appears at intervals, near Luneburg, and on the borders of the Harz mountains, (at Quedlinburg,) and there seems no reason to doubt that the whole vast plain of Northern Germany, from the Rhine to the Vistula, rests upon the cretaceous system. What remains of the Island of Heligoland consists of green sand.

The whole line of the Alps from the Salève to Vienna is bordered upon the Northern side by rocks of the cretaceous system, which are closely associated in character with both the oolites beneath, and with the tertiaries which lie above A similar observation applies to the South side of these mountains; chalky rocks range down the Apennines, and occur abundantly in the Maritime Alps, there, as well as about Geneva, intimately associated with the upper oolitic beds. Deposits of this era also lie in old valleys of the Jura mountains, which range in a North-Eastern and South-Western direction. The Pyrenees are bordered on both sides by green sand and sandy and calcareous beds, containing with many chalk fossils some of tertiary types.

Over this extensive area the mineralogical characters of the system are tolerably uniform, except in the vicinity of the Alps, where the violent disturbances to which that mountain range has been subjected appear to have entirely altered the aspect of these beds, so as to permit authors to speak of *black chalk*, which, however, is perhaps a portion of the green sand group. Over all the region already mentioned in France, in Belgium, at all the points in Northern Germany, in Poland, in Russia, Pomerania, Denmark, and Sweden, the chalk has its usual characters and appearance, and contains ananchytes and spatangi, belemnites, terebratulæ, inocerami, &c. The green sand in France, near Aix la Chapelle, along the Erzgebirge, in Poland, along the Carpathians, in Heligoland, has its usual characters. Indeed, even along the Eastern Alps, but especially in the Swiss and Savoy Alps, and the Jura, the green sands' group retains nearly its usual aspect, and exhibits its usual fossils; and an English Geologist placed at the Perte du Rhône, or amidst the rocks of the Montagne de Fiz, is at once introduced to the Geology of the vicinity. Green sand layers alternate with the upper part of the Jura oolites in the Salève, and the same phenomenon appears to happen along the Eastern Alps, (Murchison's and Sedgwick's Memoirs, *Geological Transactions*,) where some parts of this group contain fuci so as to be characterised thereby. Nummulites are associated with the green sand in the Swiss Alps, and also in the Maritime Alps, where the lower beds of the cretaceous formation consist of light-coloured limestone charged with green grains, and full of belemnites, ammonites, nautili, and pectines, and appear intimately connected with the top of the Jura limestone deposit. (De la Beche, *Manual*, 259.) Nummulitic rocks, calcareous and arenaceous, exist in Dalmatia, and form high mountains in Croatia.

On the Southern side of the Alps, the beds of the cretaceous era, which descend to the plains of Lombardy, are principally composed of white, greenish, and reddish beds, and it appears that a gradation of character may be traced through the oolitic, cretaceous, and tertiary strata here uplifted. (Murchison.) Some of the light-coloured limestones referred to the chalk are called scaglia, and the mountain of the Voirons near Geneva, yields a rock of similar nature.

Dislocations of the Cretaceous System.

Like the oolitic era, the cretaceous period appears to have been one of regular action, perhaps still more uniform than that, but not of so long duration. For we do not find its deposits to contain so many distinct suites of organic remains, nor so many remarkable *repetitions* of analogous rocks as occur in the oolitic system. The lower sandy beds of the system, indeed, may be thought to have been influenced by the convulsions which upheaved the oolites, but we cannot assent to the notion of Elie de Beaumont, that the whole cretaceous system is derived from the mechanical movements thus impressed upon the waters. The organic remains of the system sufficiently disprove this, and the great extent and uniformity of the deposit of chalk is no otherwise to be explained, than by general laws applicable to all the older and more recent calcareous strata.

That disturbances of great extent happened *somewhere* after the deposit of the chalk in England, is evident from the extraordinary abundance of sandy and gravelly accumulations, sometimes resting in hollows of the chalk, which immediately cover that stratum. A great part of the plastic clay group is of this fragmentary and tumultuary origin, and its black flint pebbles are only water-worn chalk flints. But England does not appear to have been the centre of these convulsions, nor to have been much moved by them unless bodily, and without local and violent fracture of strata. It is, indeed, very *probable*, that parts of the chalk formation, originally deposited in deeper seas, were at this time brought up and made to constitute a shore and to be liable to all the waste of the waves. And some portions might be, and probably were, raised to dry land, and exposed to the weather and the wearing of streams. But we cannot at present undertake to say where such a shore occurred, nor in what part exactly the chalk was raised into hills.

In Ireland, at this period, great eruptions of basalt happened, and broad lakes of lava covered the chalk of that Country.

In France the chalk was wasted as in England, and its flints rolled to pebbles, to constitute the pebbly beds of the plastic clay group; and this seems to have been chiefly effected by fresh-water streams, for we find in the plastic clay of France few organic remains besides terrestrial and fresh-water productions. Yet here, we believe, it is equally difficult to say what *portions* of the chalk were thus raised and exposed. The surface of the chalk in France appears to have been more wasted and furrowed than in England.

To this period, Elie de Beaumont ascribes the dislocations which in the French Alps and the South-Western extremity of the Jura, from the environs of Antibes to those of Pont d'Ain and Lons le Saulnier, present a series of dislocations in a direction North North-West. The primary mass of Mont Viso is traversed by this system of faults. The Eastern crests of the Devolny on the North of Gap, are formed of the oldest beds of the green sand and chalk, thrown up in the direction

North North-West, and raised more than 4700 English feet above the sea, while at their feet, and 2000 feet lower, the nummulitic or upper portion of the cretaceous system remains horizontal and entirely undisturbed.

Every thing belonging to this particular epoch, that is calculated to throw light on the changes then operated on the external features of the Globe, is of the highest curiosity and importance, since the probability is great that very violent and extensive convulsions, producing most remarkable alterations in Physical Geography and in other conditions of organic life, must have happened to occasion so entire and sudden a change of plants, shells, and vertebrated animals, as, notwithstanding recent discoveries of supposed intermediate strata, is admitted to have taken place after the deposition of the cretaceous system.

Some time after the above remarks were written, the third volume of Mr. Lyell's *Principles of Geology* appeared, in which that able Geologist has ventured to do what we thought too difficult to attempt, and defines in one instance what part of the ancient bed of the sea was raised at the commencement and during the continuance of the tertiary period. Combining his own observations on tertiary strata with Mr. Mantell's discoveries, he proposes the theory that the elevation of the Wealden district of Sussex and Kent was contemporaneous with, or only immediately antecedent to, the deposition of the tertiaries in those parts of the sea which are now become the basins of London and Hampshire; that the elevation of the secondary, as well as the deposition of the tertiary rocks, was produced by long continued operations of the same kind, and that as different strata were raised in the Weald, to be wasted away by the sea and atmospheric action, the tertiary deposits, thence carried to the depths of the sea, were proportionately varied. We cannot now discuss this ingenious theory, because it is connected with a very extensive argument, involving many of the fundamental views of this author, Elie de Beaumont, and Von Buch, but it will be examined in its proper place.

Table of the Organic Remains of the Cretaceous System.

PLANTS, (from M. Adolphe Brongniart.)

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Confervæ.	Confervites fasciculata		Sussex	chalk	Arnager in Bornholm.
	ægogropiloides			ditto	Ditto.
Algæ	Fucoides Brardi				Pialpenson. (Dordogne.)
	Orbignianus				Isle d'Aix, near La Rochelle.
	strictus				Isle d'Aix.
	tuberculosus				Ditto.
	Targioni	chalk	Bognor, Sussex		Les Voirons, near Florence.
	æqualis				Vernasque in the Plaisantin.
	difformis				Bidache, near Bayonne.
	intricatus				Oneille, Genoa, Florence, Vienna, Bidache.
	furcatus				Vernasque, Gênes, Florence.
	recurvus				Vernasque.
	Lyngbianus				Arnager.
	Brongniarti, Mant.	ditto	Sussex.		
Naiades	Zosterites caulinisefolia				Isle d'Aix.
	lineata				Ditto.
	Bellovisiana				Ditto.
	elongata				Ditto.
Cycadeæ	Cycadites Nilsonii			chalk	Scania.
	Thuytes aliena, Sternb.			planerkalk	Schmetschna.
	Wood, dicotyledonous	ditto	ditto.		
Leaves resembling platanus and liriodendron, Sternb.					Blankenburg, Wernigerode.

It does not appear that any of the plants of this epoch were in existence before or since.

POLYPARIA.

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Fibrosæ	Spongia plana, Phil.	chalk	Bridlington.		
	capitata, Phil.		Ditto.		
	osculifera, Phil.		Ditto.		
	convoluta, Phil.		Ditto.		
	lobata, Flem.		Lewes, Norwich.		
	marginata, Phil.		Bridlington.		
	radiciformis, Phil.		Ditto.		
	terebrata, Phil.		Ditto.		
	porosa, Phil.		Ditto, Dover.		
	lævis, Phil.		Bridlington.		
	cribrosa, Phil.		Ditto.		
	ramosa, Mant.		Ditto, Sussex		Noirmoutier.
	paradoxica		Hunstanton, Southbourn.		
	(Spongus) labyrinthicus, Mant.		Heytesbury, Lewes.		
	Townsendi, Mant.		Ditto, ditto.		
	(Siphonia) Websteri	green sand.	Isle of Wight, Southbourn.		
	curvicornis, Goldf.			marl	Westphalia.
	incrassata, Goldf.			chalk	Ditto.
	(Ventriculites) Benettiæ, Mant	chalk	Lewes, Wilts, Bridlington.		
	radiatus, Mant.	ditto	Lewes.		
	alcyonoides, Mant.	ditto	Ditto, Warminster.		
	quadrangularis, Mant.	ditto	Offham, Sussex.		

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Fibrosæ	(Choanites) subrotundus, Mant.	chalk	Lewes.		
	flexuosus, Mant.	ditto	Ditto.		
	Kœnigi, Mant.	ditto	Warminster, Lewes.		
	Halirrhoa costata, Lam.	green sand	Warminster		Normandy.
	Paramoudra	chalk	Belfast, Norfolk.		
	Alcyonium globulosum, Defr.	ditto	Sussex		Beauvais, Meudon, &c.
	pyriforme, Mant.	ditto	Ditto.		
	Serea pyriformis, Lam.	green sand	Warminster.		

Of the following fibrous polyparia described by Goldfuss from Maestricht and Westphalia, it is very probable that when better known, several will be found identical with the spongiæ and alcyoniæ of English authors. It is to be regretted that the labours of Naturalists in this difficult branch of fossil Zoology have been almost fruitless for want of cooperation. The abundance of spongoid fossils is a very remarkable character of the English and Westphalian chalk.

Achilleum glomeratum	Maestricht.	Scyphia Murchisonii	Darup.
fungiforme	Ditto.	verticillata	Maestricht, Nehou.
morchella	Essen.	mammillaris	Essen.
Manon capitatum	Maestricht.	tetragona	Ditto.
tubuliferum	Ditto.	furcata	Ditto.
pulvinarium	Ditto, Essen.	foraminosa	Ditto.
peziza	Ditto, ditto.	infundibuliformis	Ditto.
stellatum	Essen.	Sackii	Ditto.
pyriforme	Coesfeld	Tragos deforme	Ditto.
Scyphia fungiformis	Ditto.	rugosum	Ditto.
Mantellii	Ditto.	pyriforme	Ditto.
Dechenii	Ditto.	stellatum	Ditto.
Oeynhausii	Darup.	hippocastanum	Ditto.

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Carnosa.	Chenendopora fungiformis, Lam.	green sand.	Warminster.		
	Hippalimus fungoides, Lam.		Ditto.		
Corticifera	Gorgonia bacillaris, G.			chalk	Maestricht.
	——— Phil.	chalk	Bishop's Wilton, Hants.		
Cellulifera	Millepora Fittoni, Mant.	ditto	Sussex.		
	Gilberti, Mant.		Ditto.		
	antiqua? Defr.				Normandy.
	——— Bl.				Meudon.
	compressa				Maestricht.
	madreporacea				Ditto.
	Nullipora racemosa				Ditto.
	Eschara cyclostoma				Ditto.
	pyriformis.				Ditto.
	stigmatophora				Ditto.
	sexangularis				Ditto.
	cancellata				Ditto.
	arachnoidea				Ditto.
	dichotoma				Ditto.
	striata				Ditto.
	filograna				Ditto.
	disticha				Meudon.
	Cellepora ornata				Maestricht.
	hippocrepis.				Ditto.
	velamen				Ditto.
	dentata				Ditto.
	crustulenta				Ditto.
	bipunctata.				Ditto.
	escharoides				Essen.
	——— Phil.	ditto	Knapton, Yorkshire.		
	Retepora clathrata				Maestricht.
	lichenoides				Ditto.
	truncata				Ditto.
	disticha				Ditto.
	fenestrata				Nants.
	cancellata				Maestricht.
	Coscinopora infundibuliformis.			marls.	Coesfeld.
	macropora			ditto	Münster.
	Coeloptychium agaricoides			ditto	Coesfeld.
	Flustra reticularis, Lam.	ditto	Sussex, Norwich.		
	reticulata, Desm				Normandy.
	flabelliformis, Lam.				Ditto.
	tessellata, Woodw.	ditto	Norwich.		
	Ceriopora cryptopora			chalk	Maestricht.
	micropora.				Ditto, Essen, Nantu.
	anomalopora				Maestricht.
	polymorpha			marl	Essen.
	*dichotoma				Maestricht.
	milleporacea				Ditto.

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Cellulifera	Ceriopora gracilis				Essen.
	madreporacea			chalk.	Maestricht.
	tubiporacea			ditto	Ditto.
	spongites			marl	Essen.
	*clavata				Ditto.
	cribrosa				Ditto.
	verticillata			chalk.	Maestricht.
	spiralis				Ditto.
	pustulosa				Ditto.
	compressa				Ditto.
	trigona			marl	Essen.
	stellata			chalk	Maestricht, Essen.
	*diadema				Ditto.
	mitra			marl	Essen.
	venosa				Ditto.
	Lunulites cretacea, Defr.				Maestricht, Tours, Normandy.
	Orbitulites lenticulata	chalk	Sussex.	green sand.	Perte du Rhone.

Celluliferous polyparia appear at present scarce in the English chalk and green sand, yet probably, on further research, the contrast which in this respect subsists between our series and that of Maestricht and Westphalia may be diminished.

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Lamellifera	Lithodendron gracile			green sand.	Quedlinburg.
	(Caryophyllia) gibbosum				Near Bochum, Westphalia.
	Caryophyllia centralis, Mant.	chalk	Sussex, Yorkshire, Normandy.		
	conulus, Phil.	gault	Yorkshire, Cambridgeshire.		
	Fungia radiata			chalk	Aix la Chapelle.
	cancellata				Maestricht.
	coronula			marl	Essen.
	(Turbinolia) Kœnigi	chalk green sand gault	Sussex. Wilts. Cambridge, Yorkshire.		
	Diploctenium cordatum			chalk	Maestricht.
	pluma				Ditto.
	Meandrina reticulata			ditto	Maestricht.
	Astræa flexuosa				Ditto.
	geometrica				Ditto.
	clathrata				Ditto.
	escharoides				Ditto.
	textilis				Ditto.
	velamentosa				Ditto.
	gyrosa				Ditto.
	elegans				Ditto.
	angulosa				Ditto.
	geminata				Ditto.
	arachnoides				Ditto.
	rotula				Ditto.
	macrophthalma				Ditto.
	muricata				Meudon.
	stylophora				Ditto.
	Pagrus Proteus, Defr.				Ditto, Tours, Normandy.

It is probable that the whole suite of polyparia of the cretaceous system is peculiar to it. This remark is meant to apply to the Maestricht fossils as well as to the more generally recognised types of chalk and green sand.

Radiaria.

Family.	Name.	Rock.	Foreign Localities.	Rock.	British Localities.
Crinoidea	Apiocrinus ellipticus	chalk	Sussex, Wiltshire, Yorkshire	chalk	Touraine, Normandy.
	Pentacrinus caput Medusæ	gault	Yorkshire	ditto	Maestricht.
	Marsupites Milleri, Mant.	chalk	Ditto, Wiltshire, Sussex.		
	Glenotremites paradoxus, G.			marl	Speldorf, near Mulhausen.
Stellerida	Asterias quinqueloba			chalk	Maestricht, near Munster.
	———	ditto	Norwich, Wiltshire		Paris, Rouen, &c.
	regularis, Wood.		Swaffham, Lewes.		
	semilunatus	ditto	Norfolk, Wiltshire, Yorkshire.		
	lentiginosus, Wood.		Dover.		
Echinida	Cidaris regalis			ditto	Maestricht.
	scutigera				Kehlheim, Bavaria.
	crenularis				France.
	granulosa				Aix, Maestricht, Essen.
	variolaris			marl	Essen, Coesfeld.
	ornata				Essen.
	papillata, Park.	ditto	Wiltshire, Sussex, Yorkshire.		
	mammillata, Park		Wiltshire.		
	cretosa, Mant.		Lewes, Northfleet.		

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Echinida	Cidaris variolaris (*G. Trans.*)		Lewes, Lyme	chalk	Havre.
	vulgaris, Lam.				Poland.
	asterizans	green sand.	Warminster.		
	corollaris, Mant.	chalk	Sussex, Wiltshire, &c.		
	clavigera, Kœnigi		Sussex.		
	vesiculosa			marl	Essen.
	Echinus saxatilis, Park	ditto	Sussex, Norwich.		
	Kœnigi, Mant.		Sussex, Yorkshire		Moen.
	Benettiæ, Kœnigi	green sand.	Wiltshire.		
	areolatus, Wahl.		Ditto, Lyme Regis	chalk	Bodsberg in Scania.
	alutaceus			marl.	Essen.
	granulosus			sandstone	Kuhlheim.
	radiatus			marl	Essen.
	Clypeus, small species	ditto	Warminster.		
	Clypeaster Leskii			chalk	Maestricht.
	fornicatus				Munster.
	Galerites albogalerus, Leske	chalk	Lewes, Wiltshire, Yorkshire	ditto	Aix, Poland, Dieppe, &c.
	subrotundus, Leske		Lewes, Norwich, Yorkshire.		
	vulgaris, Lam		Lewes, Lyme		Aix, Dreux.
	conoideus			ditto	Perigord.
	subuculus, Lam.		Wiltshire	green sand and marl	Havre, Coesfeld, and Essen.
	depressus, Lam.				Fiz, Swisserland, Bavaria.
	canaliculatus				Buren and Brunken, Paderborn.
	sulcato radiatus			chalk	Maestricht
	Hawkinsii, Mant.	ditto	Sussex.		
	abbreviatus				Aix la Chapelle, Quedlinburg.
	Echinoneus subglobosus			ditto	Maestricht.
	placenta				Ditto.
	lampas, De la Beche	green sand.	Lyme Regis.		
	peltiformis, Wahl.				Scania.
	Nucleolites depressus			ditto	Aix la Chapelle?
	ovatus, Lam.				Maestricht.
	scrobiculatus, Lam.				Ditto.
	pyriformis				Ditto.
	lacunosus			marl.	Essen.
	cordatus				Ditto.
	carinatus			chalk	Aix, Hildesheim, Essen.
	lapis cancri				Aix, Maestricht.
	*testudinarius				Ratisbon.
	rotula, Bt.				Rouen, green sand, Mtn. de Fiz.
	castanea, Bt.			green sand	Mtn. de Fiz.
	patellaris			chalk	Maestricht.
	Ananchytes ovatus, Lam.	chalk	Sussex, Wiltshire, Norwich, Yorkshire, &c.	ditto	Meudon, Sweden, Lublin chalk, marl, Essen.
	hemisphæricus, Mant		Sussex, Yorkshire.		
	intumescens, Phil.		Yorkshire.		
	pustulosus, Lam.		Norfolk	ditto	Paris, Rouen, Moen.
	conoideus				Aubel in Limburg.
	striatus				Aix, Maestricht.
	corculum			marl	Coesfeld.
	other species, Smith	ditto	England.		
	Spatangus ornatus, Cuv.	green sand.	Lyme		Aix, Biaritz, near Bayonne.
	suborbicularis, Defr.		Ditto		Maestricht, Dives.
	argillaceus, Phil.	gault	Wiltshire, Yorkshire.		
	Murchisonianus, Mant	green sand.	Nursted, Southbourn.		
	cordiformis, Mant.	chalk	Middleham, Norwich.		
	rostratus		Brighton, Norfolk		Joigny.
	prunella, Lam.		Brighton		Maestricht.
	cor anguinum, Lam.		Norwich, Lewes, Lyme, &c.		Paris, Normandy, Burgundy, Fiz, Coesfeld, Saxony, Bohemia.
	planus, Mant.		Yorkshire, Sussex		Scania, Poland.
	hemisphæricus, Phil.		Yorkshire.		
	lævis, Defr.	ditto	Lyme	green sand	Perte du Rhone.
	bufo, Bt.			chalk	Paris, Normandy, Maestricht.
	——, Phil.	green sand.	Chute Farm, Wiltshire.		
	granulosus			ditto	Maestricht.
	subglobosus, Leske				Quedlinburg, Büren.
	nodulosus				Essen.
	radiatus, Lam.				Maestricht.
	bicordatus				Mecklenburg.
	truncatus				Maestricht.
	Bucklandi			marl	Essen.
	arcuarius, Lam. a recent species			chalk	Maestricht.
	amygdala, Lin.				Ditto.
	gibbus, Lam.				Paderborn.
	cor testudinarium				Maestricht, Quedlinburg, Coesfeld.
	bucardium				Aix.
	lacunosus, Lin.				Aix, Quedlinburg.
	retusus, Park.	ditto	Wilts.		
	punctatus, Park		Ditto.		

The distinctness of the form and characters of the incrusted radiaria, permits in general a satisfactory decision concerning their specific identification. On this account, no less than from the general diffusion of these fossils, the echinida, stellerida, and crinoidea ought to afford the most certain evidence concerning the laws of geographical distribution of animals during the cretaceous epoch. It cannot escape notice that a great number of species of echinida belong to extinct genera. It is remarkable that the genus spatangus, of which one or two species occur in oolite and several exist in the present seas, seems to have arrived at its maximum of abundance in the cretaceous epoch; and that the extinct genus, ananchytes, which is especially abundant and widely diffused in chalk, has not been found in the subjacent oolites, nor in the true tertiaries above the Maestricht beds. It is possible that amongst the echinida a very few species are identical with some found in the oolitic strata, (as galerites depressus, cidaris variolaris, &c.) but in general the species appear to be decidedly peculiar.

Conchifera.

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Plagymyona	Fistulana pyriformis, Mant.	gault.	Willingdon, Sussex.		
	personata, Mant.	chalk	Sussex.		
	Pholas constricta, Phil.	gault.	Yorkshire.		
	Teredo ? —— Hæn.			chalk	Maestricht.
	Pholadomya decussata, Phil / Cardium decussatum, Sow.	ditto	Specton; chalk Sussex.		
	Panopæa plicata	green sand.	Sandgate	green sand.	Osterfeld.
	Mya mandibula		Sussex, Isle of Wight, Devizes.		
	depressa	gault.	Yorkshire.		
	phasiolina, Phil.		Ditto.		
	plana			ditto.	Ditto.
	—— ? Lonsdale.	chalk	Near Calne.		
	Lutraria striata	green sand.	Lyme.		
	carinifera	chalk.	Ditto.		
	gurgitis, Bt.			ditto	Perte du Rhone, Sweden.
	Amphidesma —— Phil. M.S.	green sand.	Hythe.		
	Corbula striatula	ditto	Parham, Pulborough.		
	gigantea		Blackdown.		
	lævigata		Ditto.		
	elegans		Ditto.		
	punctum, Phil.	gault.	Ditto.		
	caudata, Nils.				Köping.
	anatina, Desh.			ditto.	Schonen, Hæn.
	Crassatella latissima, Hæn.			chalk	Maestricht.
	Tellina æqualis, Mant.	green sand.	Parham.		
	inæqualis		Ditto, Blackdown.		
	striatula		Blackdown.		
	—— Phil.	gault.	Yorkshire.		
	Lucina sculpta, Phil.		Ditto.		
	lævis, Phil.		Ditto.		
	Crassina / Astarte. } striata		Blackdown, Devizes.		
	Thetis major	green sand.	Blackdown, Sussex, Devizes.		
	minor		Sussex, Isle of Wight, &c.		
	Venus angulata	ditto.	Blackdown, Parham.		
	caperata		Lyme, Blackdown.		
	ovalis		Parham.		
	faba		Parham, Isle of Wight.		
	parva		Lyme, Isle of Wight, Sussex.		
	lineolata		Blackdown.	green sand.	Bochum.
	plana		Ditto.		
	Ringmeriensis, Mant	chalk.	Ringmer, Middleham.		
	Cardium Hillanum	green sand.	Blackdown.		
	proboscideum		Near Collumpton, Devon.		
	umbonatum		Blackdown.		
	granulosum, Woodw.	chalk.	Norwich.		
	bullatum, Lam.			chalk.	Aix la Chapelle.
	Cardita Esmarkii, Nils.				Scania.
	tuberculata	green sand.	Devizes, Lyme.		
	modiolus, Nils.				Ditto.
	crassa			ditto.	Doué.
	Isocardia angulata, Phil.	gault.	Yorkshire.		
	Trigonia spinosa	green sand.	Blackdown, Pulborough, Lyme.		
	dædalea		Parham, Haldon, &c. Isle of Wight.		
	aliformis		Pulborough, Eddington, Wilts.		Altenberg.
	eccentrica		Pulborough, Lyme, Blackdown.		
	spectabilis		Blackdown.		

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Plagymyona	Trigonia rugosa			green sand.	Perte du Rhone.
	scabra		Lyme		Rouen, Perte du Rhone.
	affinis		Parham, Haldon.		
	pennata		Teignmouth.		
	nodosa		Hythe.		
	pumila, Nils.				Koping, Balsberg.
	arcuata, Lam.				Aix la Chapelle.
	Cucullæa decussata	green sand.	Parham, Feversham.	chalk.	Rouen.
	glabra	ditto.	Lyme. Blackdown.		
	carinata	ditto.	Ditto, ditto.		
	fibrosa	ditto.	Ditto, ditto.		
	costellata	ditto.	Lyme. Cullumpton.		
	auriculifera, Hæn.			ditto.	Beauvais.
	crassatina			ditto.	Ditto.
	———	chalk.	Sussex, (Mant.) Yorksh. (Phil.)		
	Arca carinata	green sand.	Devizes. Lyme. Nursted.		
	subacuta		Hamsey		Maestricht.
	exaltata, Nils.				Carlshamen, Sweden, Aix la Chapelle.
	rhombea, Nils.				Balsberg, Sweden.
	ovalis, Nils.				Koping, Scania.
	clathrata, Hæn.				Angers, Saumur.
	Pectunculus sublævis	ditto	Blackdown.		
	umbonatus	ditto	Haldon.		
	lens, Nils.				Balsberg, Koping, Sweden.
	Nucula impressa	ditto	Parham, Blackdown.		
	antiquata	ditto	Parham		
	angulata	ditto	Blackdown.		
	ovata, Mant.	gault	Ringmer, Folkstone, Yorks.		
	subrecurva, Phil.		Yorkshire.		
	pectinata, Mant.		Sussex		Boulonnais.
	undulata		Folkstone.		
	producta, Nils.				Kunberga, Scania.
	truncata, Nils.				Ditto, ditto.
	panda, Nils.				Ditto, ditto.
	Modiola parallela	green sand.	Maidstone.		
	*bipartita	ditto	Parham Park.		
	æqualis	ditto	Ditto.		
	*pallida		Fonthill, Wilts.		
	Mytilus lanceolatus	ditto	Blackdown, Parham.		
	edentulus	ditto	Blackdown.		
	lævis, Defr.			ditto	Bougival, Paris.
	problematicus, Hæn.			green sand.	Bochum.
	Pachyma gigas	chalk	Lyme.		
	Mytiloides labiatus, Schl.	ditto	Wilts		Aix la Chapelle, Quedlinburg.
Mesomyona	Pinna tetragona	green sand.	Devizes.		
	gracilis, Phil.	gault	Yorkshire.		
	sulcata, Woodw.	chalk	Norwich.		
	affinis, Hæn.			chalk	Near Saumur.
	flabellum, Hæn.				Bochum.
	nobilis, Hæn.				Ditto.
	restituta, Hæn.				Valkenburg.
	quadrivalvis, Hæn.				Cotentin, Saumur.
	Gervillia *aviculoides	green sand.	Parham, Petersfield.		
	*acuta	ditto	Parham.		
	solenoides	ditto	Ditto, Isle of Wight, Wilts.		Maestricht, Normandy.
	Clavicula cærulescens, Nils.				Sweden.
	———, Mant.	chalk	Sussex.		
	Crenatula producta		Shefford, Bedfordshire.		
	*ventricosa				Bochum. (Hæn.)
	Inoceramus, including Catillus, Cuv. gryphæoides		Lyme, Ringmer.		
	sulcatus		Folkstone, Ringmer, Cambridge		Perte du Rhone, Fiz, Scania.
	tenuis		Hamsey.		
	Cripsii		Ditto.		
	concentricus		Folkstone, Lyme, &c.		Perte du Rhone, Essen.
	pictus		Guildford.		
	Cuvieri	ditto	Royston, Lewes, Yorkshire.		Rouen, Tours, Scania.
	Brongniarti	ditto	Lewes, Yorkshire		Quedlinburg, Poland, Scania
	cranium, Phil.	ditto	Hunmanby.		
	cordiformis	ditto	Gravesend.		
	mytiloides	ditto	Norwich, Wilts, Sussex.		
	striatus, Mant.	ditto	Wilts, Lewes.		
	Lamarckii, Mant.	ditto	Sussex. Dover.		
	undulatus, Mant.	ditto	Lewes, Heytesbury.		
	Websterii, Mant.	ditto	Sussex.		
	latus, Mant.	ditto	Ditto.		
	involutus	ditto	Ditto, Norfolk.		

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Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Mesomyona	Inoceramus digitatus	chalk	Essex.		
	rugosus, Hæn.				Quedlinburg.
	Exogyra haliotidea	green sand.	Wilts		Scania, Essen.
	conica	ditto	Ditto, Sussex, Blackdown.		Scania.
	recurvata	ditto	Haldon.		
	plicata	ditto	Ditto.		
	canaliculata	ditto	Wilts.		
	undata	ditto	Blackdown.		
	cornuarietis, Nils.				Ditto.
	laciniata, Nils.				Ditto
	sinuata		Isle of Wight, Yorksh Kent		Grande Chartreuse.
	Gryphæa vesiculosa	ditto	Wilts, Sussex	green sand.	Bouches du Rhone.
	columba, Lam.		Lyme, Longleat		Havre, Poland, Saxony.
	globosa	chalk	Norwich, Lewes, &c.		
	aquila, Bt.				Perte du Rhone.
	auricularis, Bt.			chalk	Perigueux, Poland, Grande Chartreuse, Vaucluse.
	plicata, Lam.			green sand.	Boesingfeld; chalk, Saumur.
	truncata, Goldf.				Maestricht.
	Sphæra corrugata	green sand.	Isle of Wight.		
	Ostræa vesicularis, Lam.	chalk	Sussex, Norwich, &c.	chalk	Meudon, Maestricht, Scania.
	semiplana, Mant	ditto	Sussex.		
	canaliculata	ditto	Ditto, Norfolk.		
	carinata	green sand.	Wilts, Lyme, &c.	green sand.	Normandy, Boulogne, Bochum.
	macroptera		Folkstone.		
	aliformis, Woodw.	chalk	Norwich.		
	tricarinata, Woodw	ditto	Ditto.		
	digitata, Woodw.	ditto	Ditto.		
	serrata, Defr.			chalk	Sweden, Maestricht, Dreux.
	lateralis, Nils.				Scania, Essen.
	clavata, Nils.				Sweden.
	hippopodium, Nils.				Ditto.
	*acuminata				Scania.
	curvirostris, Nils.				Ditto.
	flabelliformis, Nils.				Sweden, Essen.
	pusilla, Nils.				Scania.
	lunata, Nils.				Ditto.
	parasitica, Hæn.			green sand.	Bochum.
	truncata, Hæn.			ditto	Griesenbeck.
	Pecten quinquecostatus	chalk	Sussex; green sand, Blackdown, Lyme, Wilts.	chalk	Meudon, Saumur; green sand, Perte du Rhone, Sweden.
	quadricostatus	green sand.	Sussex, Blackdown, Wilts.	ditto	Maestricht, Normandy; green sand, Grande Chartreuse, Saxony.
	Beaveri	chalk	Sussex.		
	triplicatus, Mant.	ditto	Ditto.		
	orbicularis	ditto, &c.	Ditto, Wilts		Sweden, Aix la Chapelle.
	obliquus	green sand.	Ditto, ditto.		
	asper	ditto	Wilts		Poland, Bochum, Hatteren.
	nitidus, Sow. / intextus, Bt.	chalk	Norwich, Brighton		Havre, Aix la Chapelle.
	radiatus, Woodw.	ditto	Norwich.		
	sexcostatus, Woodw.	ditto	Ditto.		
	concentricus	ditto	Ditto.		
	septemplicatus, Nils.				Scania.
	cretosus, Defr.				Paris.
	arachnoides, Defr.				Ditto, Normandy.
	membranaceus, Nils				Scania.
	dentatus, Nils.				Ditto.
	extextus, Bt				Havre, Normandy, Angers.
	serratus, Nils.				Sweden.
	multicostatus, Nils.				Ditto.
	undulatus, Nils				Scania.
	subaratus, Nils.				Sweden.
	pulchellus, Nils.				Ditto.
	lineatus, Nils.				Ditto.
	virgatus, Nils.				Ditto.
	lævis, Nils				Ditto, Aix la Chapelle.
	inversus, Nils				Sweden.
	asperrimus, Hæn			green sand.	Hardt.
	gracilis, Hæn.				Aix la Chapelle.
	gryphæatus, Hæn.				Ditto.
	regularis, Schl.			chalk	Maestricht.
	sulcatus, Hæn				Ditto; green sand, Hardt.
	versicostatus, Hæn.			green sand.	Aix la Chapelle, Minden.
	Plagyostoma spinosum	chalk	Sussex, Wilts	ditto	France, Poland, Saxony, Sweden.
	Hoperi, Mant.	ditto	Ditto.		
	Brightonense, Mant.	ditto	Ditto.		
	elongatum	ditto	Ditto.		
	asperum, Mant.	ditto	Ditto.		
	? pectinoideum			ditto	Perte du Rhone.
	ovatum, Nils.				Sweden.

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Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Mesomyona	Plagiostoma semisulcatum, Nils.				Sweden, Saumur.
	Mantelli, Bt.	chalk	Dover		Denmark.
	granulatum, Nils.				Sweden.
	elegans, Nils.				Ditto.
	pusillum, Nils.				Ditto.
	turgidum, Lam.			chalk	Saintes; green sand, Osterfeld.
	Podopsis or Dianchora lata	chalk	Sussex.		
	obliqua, Mant.	ditto	Ditto.		
	striata	ditto	Yorkshire		Havre, Essen, Bochum.
	truncata, Lam.		Lyme	ditto	Normandy, Touraine, Sweden.
	lamellata, Nils.				Sweden.
	Plicatula inflata	ditto	Sussex; green sand, Wilts.		
	pectenoides	ditto	Sussex; gault, Cambridge.		
	Spondylus? strigilis, Bt.			green sand	Perte du Rhone.
Rudista	Sphaerulites dilatata, Des Moulins			chalk	Royan, Talmont, mouth of the Gironde.
	Bournonii, Des M.			ditto	Royan, Talmont, Vallée de la Couze, Dordogne.
	ingens, Des M.			ditto	Royan, Talmont.
	Hœninghausii, Des M.			ditto	Ditto, ditto, Languais, Dordogne.
	foliacea, Lam.			ditto	Isle d'Aix.
	Jodamia, Des M.			ditto	Mirambeau, Charente Inférieure.
	Jouannetii, Des M.			ditto	Vallée de la Couze, Perigord.
	crateriformis, Des M.			ditto	Royan, Languais.
	Moulinii, Goldf.			ditto	Maestricht.
	Hippurites radiosa, Des M.			ditto	Cendrieux, Perigord.
	cornu pastoris, Des M.			ditto	Pyles, Perigueux.
	striata, Defr.			ditto	Alet, Aude.
	sulcata, Defr.			ditto	Ditto, ditto.
	dilatata, Defr.			ditto	Ditto, ditto.
	bioculata, Lam.			ditto	Ditto, ditto.
	fistula, Defr.			ditto	Ditto, ditto.
	undetermined			ditto	In Sussex chalk. (Mantell.)
Brachiopoda	Terebratula subrotunda	chalk	Sussex, Norwich, &c.	green sand	Bochum.
	carnea	ditto	Norwich, Sussex	ditto	Bochum; chalk, Meudon.
	ovata	ditto	Sussex; green sand, Sussex	ditto	Bochum, Scania.
	undata	ditto	Sussex.		
	elongata	ditto	Ditto.		
	biplicata	green sand	Ditto, Wilts, Cambridge.		
	lata	ditto	Sussex, Devizes.		
	subundata	chalk	Yorkshire	chalk	Rouen.
	plicatilis	ditto	Norwich, Sussex, Gravesend	ditto	Meudon, Moen; green sand, Grande Chartreuse.
	subplicata, Mant.	ditto	Sussex, Yorkshire, Wilts	ditto	Tours, Beauvais, Maestricht.
	Mantelliana	ditto	Sussex.		
	rostrata	ditto	Ditto.		
	Martini, Mant.	ditto	Ditto.		
	squamosa, Mant.	ditto	Ditto.		
	pentagonalis, Phil.	ditto	Yorkshire.		
	lineolata, Phil.	gault	Speeton, Yorkshire.		
	Defrancii, Bt.	chalk&gault	Sussex, Yorkshire		Meudon, Sweden, Maestricht.
	alata, Lam.			ditto	Meudon, Sweden.
	octoplicata			ditto	Dieppe, Sweden; green sand, Quedlinburg.
	gallina, Bt.	chalk	Norwich	green sand	Perte du Rhone, Normandy.
	ornithocephala?			ditto	Perte du Rhone, Fiz.
	pectinata	green sand	Wilts.		Normandy, Havre, Scania.
	lyra	ditto	Ditto.		
	semiglobosa	chalk	Yorkshire		Sweden, Moen, Bochum.
	obtusa	green sand	Cambridge	ditto	Quedlinburg.
	obesa	chalk	Warminster	chalk	Baude Kundert.
	dimidiata	green sand	Stalbon, Wilts	green sand	Havre.
	ovoides			ditto	Bochum.
	curvirostris, Nils.				Scania.
	recurva, Defr.				Maestricht, Normandy.
	lævigata, Nils.				Scania.
	rhomboidalis, Nils.				Sweden.
	triangularis, Wahl.				Scania.
	longirostris, Wahl.				Sweden.
	aperturata, Schl.			chalk	Essen.
	chrysalis, Schl.			ditto	Maestricht.
	curvata, Schl.			green sand	Quedlinburg
	dissimilis, Schl.			chalk	Speldorf; green sand, Bochum.
	lacunosa, Schl.			green sand	Quedlinburg.
	microscopica, Fond.			chalk	Maestricht.
	nucleus, Defr.			green sand	Bochum, Quedlinburg.
	peltata, Hœn.			chalk	Maestricht.
	semistriata, Lam.			green sand	Bochum.
	varians, Hœn.			chalk	Essen.
	vermicularis, Schl.			ditto	Maestricht.

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Family	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Brachiopoda	Terebratula ? vitrea, Lam.			chalk	Essen.
	sella	green sand.	Hythe.		
	depressa	ditto	Faringdon.		
	nuciformis	ditto	Ditto.		
	oblonga	ditto	Sandgate.		
	truncata	ditto	Faringdon.		
	Gibbsiana	ditto	Folkstone, Hythe.		
	pisum	marl	Sussex.		
	striatula	gault	Ditto, Yorkshire.		
	Gervillii, Woodw.	chalk	Norwich.		
	rigida	ditto	Norfolk.		
	obliqua	ditto	Ditto, Ramsgate.		
	(Magas) pumila	ditto	Norwich, Hants		Meudon, Maestricht.
	magna, Woodw.	ditto	Norfolk		
	punctata, Woodw.	ditto	Ditto.		
	Crania Parisiensis, Defr.	chalk	Norwich, Brighton	chalk	Meudon.
	ornata, Defr.		Swaffham	ditto	Normandy, Sweden.
	antiqua, Defr.			ditto	Normandy, Schlenacken.
	stellata, Defr.			ditto	Normandy.
	spinulosa, Nils.			ditto	Sweden, Maestricht.
	tuberculata, Nils.			ditto	Scania
	nummulus, Lam.			ditto	Schlenacken, in Scania.
	nodulosa, Hæn.			ditto	Maestricht, Sweden.
	Orbicula	green sand.	Sussex ; gault, Yorkshire.		
	Thecidea hieroglyphica, Defr			ditto	Essen.
	radians, Defr.			ditto	Maestricht, Normandy.
	recurvirostra, Defr.			ditto	Ditto, ditto.

Of 100 conchifera belonging to the chalk system, 32 are plagymyonous, 10 mesomyonous, 5 imperfectly known are classed as rudista, and 23 brachiopodous. They are mostly unknown in the strata above or below. The great predominance of mesomyonous bivalves is a feature common to this and the oolitic system It must be remarked, however, that it is particularly difficult to settle accurately the number of species of the genera ostrea, exogyra, and inoceramus.

Mollusca.

Family.	Name	Rock.	In British Localities.	Rock.	In Foreign Localities.
Gasteropoda	Dentalium decussatum	gault	Sussex.		
	medium	green sand.	Blackdown.		
	nitens, Hæn.			chalk	Maestricht
	septangulare	ditto	Belfast.		
	striatum, Mant.		Sussex.		
	ellipticum, Mant.		Ditto.		
	fissura, Hæn			green sand.	Scania.
	——, Nils.		Ditto.		Sweden.
	Patella lævis	ditto	Blackdown.		
	ovalis, Nils	ditto			Balsberg.
	——, Mant Lons.		Sussex, Wilts.		
	Pileopsis ——, Mant		Sussex.		
	Helix ? Gentii	ditto	Devizes.		
	Auricula incrassata	chalk	Sussex ; green sand, Blackdown	ditto	Rouen, Perte du Rhone, Fiz.
	obsoleta, Phil.	gault	Speeton, Yorkshire.		
	turgida			ditto	Scania.
	Melania ? ——, Phil.	ditto	Speeton.		
	Ampullaria canaliculata, Mant.	ditto	Sussex.		
	spirata, Hæn.			chalk	Maestricht.
	——, Bt.			green sand.	Montagne de Fiz.
	Planorbis radiatus	green sand.	Haldon.		
	Paludina extensa		Blackdown.		
	Nerita rugosa, Hæn.			chalk	Maestricht.
	Natica canrena ? Park.	ditto	Parham, Blackdown.		
	Retzii, Nils.				Balsberg.
	——, Lons. Mant.	ditto	Wilts, Sussex.		
	Sigaretus concavus, Hæn.			green sand.	Bochum.
	Delphinula ——, Phil.	gault	Speeton.		
	Turbo carinatus, Hæn.			ditto	Coesfeld.
	moniliferus	green sand.	Blackdown.		
	conicus		Ditto.		
	rotundatus		Ditto.		
	pulcherrimus, Bean.	gault	Speeton.		
	sulcatus, Nils			chalk	Koping.
	Turritella granulata	green sand.	Blackdown.		
	costata		Ditto.		
	duplicata, Hæn.			chalk	Maestricht.
	terebra, Hæn.			green sand.	Wedderslebeu.
	Pleurotomaria ——, Hæn.			chalk	Maestricht.
	Trochus Basteroti, Bt.	chalk	Lewes.	ditto	Paris, Köping.

Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Gasteropoda	Trochus inæqualis	chalk	Sussex.		
	onustus, Nils.			chalk	Koping.
	gurgitis, Bt.	green sand.	Lyme.	green sand.	Perte du Rhone, Fiz.
	Rhodani, Bt.		Southbourn, Lyme	ditto	Ditto, ditto.
	cirroides, Bt.			ditto	Ditto, ditto.
	linearis, Mant.		Sussex.		
	agglutinans?		Ditto.	ditto	Aix la Chapelle.
	bicarinatus	ditto	Ditto.		
	reticulatus?	gault	Speeton.		
	———, Phil. MS.	green sand.	Hythe.		
	Solarium tabulatum, Phil.	gault	Speeton.		
	Cirrus depressus Mant.	chalk	Sussex.		
	plicatus		Folkstone, Norlington, Sussex.		
	Sowerbii, Mant.		Hamsey.		
	granulatus.		Lewes.		
	perspectivus?		Ditto, Northfleet.		
	——— Phil.	green sand.	Hythe.		
	Cerithium excavatum			ditto	Perte du Rhone, Aix la Chapelle.
	Pyrula planulata, Nils.			chalk	Koping.
	minima, Hæn.			green sand.	Aix la Chapelle.
	Murex quadratus	ditto	Blackdown.		
	calcar	ditto	Ditto.		
	Rostellaria anserina, Nils.			chalk	Koping.
	Parkinsoni, Mant.	ditto	Sussex, Yorkshire	green sand.	Bochum, Coesfeld.
	calcarata.	ditto	Blackdown.		
	fissura, Lam.			ditto	Aix la Chapelle.
	Pterocerus maximum, Hæn				Martigues.
	Strombus papilionatus, Hæn.			chalk	Maestricht, Aix la Chapelle.
	Dolium nodosum	chalk	Clayton, Sussex.		
	striatum, Woodw.	ditto	Norwich.		
	Eburna ———, Bt.	ditto	Sussex.	green sand.	Perte du Rhone.
	Voluta ambigua, Mant.	ditto	Ditto.		
	Lamberti?			chalk	Maestricht. (Hæn.)

The numerical predominance of the holostomatous gasteropoda over those which have a notched or canaliferous mouth, is rather less conspicuous in the chalk than in the oolitic rocks; but yet it forms a remarkable contrast with the enumeration of species in the tertiary deposits. Probably all the species are peculiar.

Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Cephalopoda	Planularia elliptica, Nils.				Charlottenlund, Sweden.
	angusta, Nils.				Koping, Scania.
	Nodosaria sulcata, Nils.			chalk and green sand	Scania.
	lævigata, Nils.			chalk	Ditto.
	Belemnites mucronatus, Schl.	chalk.	Sussex, Wilts, Norfolk, Yorkshire	ditto	Meudon, Maestricht, Poland, Sweden, Aix la Chapelle, Normandy.
	granulatus, Defr.	ditto	Lewes.		
	lanceolatus, Schl.	ditto	Hamsey		Quedlinburg.
	Listeri	gault	Sussex; red chalk, Yorkshire.		
	attenuatus	ditto	Sussex, Folkstone.		
	minimus, Miller	ditto	Folkstone.		
	mammillatus, Nils.				Ignaberga in Scania.
	scaniæ, Nils.				Scania.
	Baculites anceps, Nils.			chalk	Balsberg.
	obliquatus	chalk.	Lewes, Hamsey.	ditto	Scania.
	Faujasii.	ditto	Norwich.	ditto	Paris, Sweden, Maestricht.
	vertebralis, Lam.			ditto	Maestricht, Normandy.
	triangularis, Desm.			ditto	Maestricht.
	Hamites armatus	ditto	Sussex. Oxon.		
	maximus	gault	Sussex, Yorkshire.		
	intermedius	ditto	Ditto, ditto.	green sand.	Aix la Chapelle.
	tenuis	ditto	Sussex.		
	rotundus	ditto	Ditto, Yorkshire.	ditto	Perte du Rhone, Aix la Chapelle.
	compressus	ditto	Sussex	ditto	Nice.
	raricostatus, Phil.	ditto	Speeton.		
	Beanii, Y. and B.	ditto	Ditto.		
	Phillipsii, Bean.	ditto	Ditto.		
	spinulosus	green sand.	Blackdown.		
	gigas	ditto	Hythe.		
	grandis	ditto	Kent.		
	plicatilis, Mant.	gault	Speeton, Sussex.		
	alternatus, Mant.	ditto	Ditto, ditto.		
	ellipticus, Mant.	ditto	Sussex	chalk	Normandy.
	attenuatus. Mant.	ditto	Ditto, Speeton.		
	funatus, Bt.			green sand.	Perte du Rhone, Fiz.
	canteriatus, Bt.			ditto	Perte du Rhone.
	virgulatus, Bt.			ditto	Mont de Fiz.
	cylindricus, Defr.			chalk	Normandy.

Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Cephalopoda	Hamites Parkinsoni		Wilts.		
	gibbosus	gault	Folkstone.		
	spiniger	ditto	Ditto.		
	tuberculatus.	ditto	Ditto.		
	turgidus	ditto	Ditto.		
	nodosus	ditto	Ditto.		
	baculoides, Mant.	ditto	Ditto.		
	———, Phil. MS.	ditto	Ditto.		
	Scaphites obliquus			chalk	Rouen; green sand, Mont de Fiz.
	costatus, Mant.	chalk	Sussex.		
	striatus, Park.	ditto	Ditto.	ditto	Rouen.
	———, Desn.			ditto	Normandy.
	Turrilites costatus	ditto	Sussex, Wilts.	ditto	Rouen, Havre.
	undulatus, Mant	ditto	Sussex.		
	tuberculatus	ditto	Ditto.		
	Bergeri, Bt.			green sand.	Perte du Rhone, Fiz.
	Babeli			ditto	Mont de Fiz.
	——— Risso.			ditto	Maritime Alps.
	obliquus	green sand.	Devizes.		
Falciferi	Ammonites cinctus, Mant.	chalk	Sussex.		
	Deluci, Bt.				Perte du Rhone, Mont de Fiz.
Amalthei	Ammonites Stobæi, Nils.			green sand.	Kopingernolla.
	Selliguinus, Bt.			chalk	Lublin, Poland, Essen; green sand, Fiz.
	Beudanti, Bt.			green sand.	Perte du Rhone.
	Lamberti ? Sow.	gault	Yorkshire.		
Macrocephali	Nutfieldiensis	green sand.	Nutfield, Wilts.		
	Lewesiensis, Mant.	chalk	Sussex	chalk	Essen, Toplitz.
	peramplus, Mant.	ditto	Ditto.		
	nodosoides, Sternb.				Bohemia.
	trisulcosus, Phil.	gault	Yorkshire.		
	rotula	ditto	Ditto.		
	venustus, Phil.	ditto	Ditto.		
	concinnus, Phil.	ditto	Ditto.		
	marginatus, Phil.	ditto	Ditto.		
Armati	nucleus, Phil.	ditto	Ditto.		
	Rotomagensis, Bt.	chalk	Sussex, Wilts.	ditto	Rouen.
	Mantelli	ditto	Sussex	ditto	Saumur, Bochum, Hanover.
	tetrammatus et monile	ditto	Ditto: green sand, Blackdown.		
	hippocastanum	ditto	Lyme.		
	Woolgari, Mant	ditto	Sussex.		
	rusticus	ditto	Ditto, Lyme.	ditto	Bochum.
	rostratus	ditto	Sussex, Oxfordshire.		
	navicularis, Mant.	ditto	Sussex.		
	clavatus, De Luc.			green sand.	Fiz
	Gentoni, Defr.	gault	Ditto.	chalk	Rouen.
	hystrix, Phil.	ditto	Yorkshire.		
	catinus, Mant.	chalk	Sussex.		
	catillus, Mant.	ditto	Ditto.		
Dentati	splendens	gault	Ditto, Kent.		
	virgatus, Goldf.			green sand.	Moscow.
	inflatus	green sand.	Wilts.	ditto	Perte du Rhone, Rouen, Havre, Fiz.
	lautus, Mant.	gault	Sussex, Kent.		
	auritus, Mant.	ditto	Ditto, ditto.		
	dentatus	ditto	Ditto, Wilts.		
	cauteriatus, Bt.			ditto	Buet.
	? varicosus	green sand.	Blackdown.	ditto	Perte du Rhone.
	? denarius	ditto	Ditto.		
	? Goodhallii	ditto	Ditto, Lyme, Sussex.		
	Bennettiæ	gault	Wilts.		
	proboscideus	ditto	Kent.		
	? planus, Mant.	ditto	Yorkshire, Sussex.		
Ornati	Ammonites varians	chalk	Sussex, Wilts	ditto	Fiz, Bochum; chalk, Rouen.
	coupei, Bt.			ditto	Rouen.
Flexuosi	falcatus	ditto	Sussex	chalk	Ditto.
	curvatus	ditto	Ditto.		
	constrictus			ditto	Lublin, Poland.

The following species are difficult to arrange under any of Von Buch's tribes.

Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
A. undatus	chalk	Sussex.		
planulatus	green sand.	Ditto.		
complanatus, Mant.	chalk	Ditto.		
lævigatus	gault	Ditto.		
parvus ?	ditto	Speeton.		
curvinodus, Phil.	ditto	Ditto.		
De Luci, Bt.			green sand.	Perte du Rhone.
subcristatus, De Luc.			ditto	Ditto.

Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
	A. cristatus	gault	Folkstone.		
	minutus	ditto	Ditto.		
Cephalopoda	Nautilus elegans	chalk	Sussex; green sand, Wilts	chalk	Rouen; green sand, Havre.
	expansus	ditto	Sussex.		
	inæqualis	gault	Ditto; green sand, Wilts.		Maestricht ?
	simplex	green sand	Blackdown	ditto	Rouen; green sand? Aix la Chapelle.
	aperturatus			ditto	Maestricht.
	undulatus	ditto	Ditto	green sand.	Bochum.
	pseudopompilius, Schl.				Rouen, Perigueux.
	obscurus, Nils.				Koping.
	radiatus	ditto	Molton, Devon.		
	(Lenticulites) Comptoni	ditto	Wilts	chalk	Scania.
	cristella			ditto	Charlottenbund, Sweden.
	Lituolites nautiloidea, Lam.			ditto	Paris.
	difformis			ditto	Ditto.
	Nummulites lenticularia, (Hæn.)			ditto	Maestricht; green sand, Aix la Chapelle.
	Faujasii, (Hæn.)			ditto	Maestricht.
	———			green sand.	Alps of Savoy, Dauphiné, and Provence, Maritime Alps; chalk, Wimbohla, Saxony, Pyrenees.

The cephalopoda of the cretaceous system are mostly peculiar to it; and not only minutely, but very obviously, and often generically characteristic of it. Hamites, baculites, scaphites, turrilites, the dentated ammonites of Von Buch, are exclusively confined to the gault, green sands, and chalk. It is very remarkable how nearly the whole series of ancient cephalopoda ends with the chalk, and without being represented, except in a very small degree, by new forms of the same class, seems to yield place to a vast augmentation of the number of the gasteropodous mollusca, which through all the tertiary system maintain that numerical predominance over the conchifera which is observed in the actual system of Nature. The names in the preceding lists are chiefly taken from Sowerby's *Mineral Conchology*.

ANNULOSA.

Name.	Rock.	In British Localities.
Vermicularia (Vermetus of authors) polygonalis	green sand	Hythe.
concavus	ditto	Sussex, Wilts.
umbonata	chalk	Sussex.
Sowerbii	ditto	Ditto; gault, Speeton.
Serpula carinella	green sand	Blackdown.
antiquata	ditto	Wilts.
rustica	gault	Folkstone.
articulata	ditto	Ditto.
ampullacea	chalk	Sussex, Norfolk.
plexus	ditto	Sussex.
obtusa	ditto	Parham, Norfolk.
fluctuata	ditto	Norwich.
macropus	ditto	Norfolk.
spirulæa	ditto	Norwich.
granulata	ditto	Ditto.
plana, Woodw.	ditto	Ditto.

The difficulty of determining species in these variable shells is such, as to throw great doubt over these determinations, made for the most part from single specimens. Objections of the same kind strike us on examining the twenty-one species of annulosa figured by Goldfuss from the cretaceous strata of Westphalia and Maestricht. The following list contains their names and localities.

Name.	Rock.	In Foreign Localities.
Serpula trachinus, G.		Essen.
lophioda, G.		Ditto.
lævis, G.		Ditto.
triangularis, Mün.		Rinkerode near Munster.
draconocephala, G.		Maestricht.
depressa, G.		Essen.
rotula, G.		Regensburg.
quadricarinata, G.		Ditto.
cincta, G.		Essen, Coesfeld, Aix.
arcuata, Mun.		Regensburg.
subtorquata, Mun.		Near Munster.
sexangularis, Mün.		Ditto.
sexsulcata, Mün.		Amberg.
Noeggerathii, Mün.		Near Munster.
erecta, G.		Maestricht.

Name.	Rock.	In Foreign Localities.
Serpula amphisbæna, G.	....	Maestricht, Bochum.
spirographis, G.	....	Essen.
parvula, G.	....	Ditto.
subrugosa, Mün	....	Baumberg near Munster.
crenato striata, Mün.	....	Ditto.
sulcata, Mün.	....	Rinkerode near Munster.

Crustacea.

Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Astacus Leachii, Mant.	chalk	Sussex.		
ornatus, Phil.	gault	Speeton.		
Sussexiensis, Mant.	chalk	Sussex.		
longimanus, Sow.	green sand.	Lyme.		
——— Mant.	gault	Sussex.		
——— Phil.	ditto	Speeton.		
Palinurus ——, N. S. Phil.	ditto	Ditto, Yorkshire.		
Pagurus Faujasii, Desm.	chalk	Sussex	....	Maestricht.
Scyllarus Mantelli, Desm.	ditto	Ditto.		
Eryon ——— Mant.	ditto	Ditto.		
Arcania ——— Mant.	gault	Ditto.		
Etyæa ——— Mant.	ditto	Ditto.		
Corystes ——— Mant.	ditto	Ditto.		

Cirripeda.

Name.	Rock.	In British Localities.
Pollicipes sulcatus	chalk	Lewes, Norwich.
maximus	ditto	Northfleet.

Pisces.

Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Squalus, compared to S. mustelus, Mant.	chalk	Sussex.		
----- S. galeus, Mant.	ditto	Ditto.		
Muræna Lewesiensis, Mant.	ditto	Ditto.		
Zeus Lewesiensis	ditto	Ditto.		
Salmo? Lewesiensis, Mant.	ditto	Ditto.		
Amia? Lewesiensis, Mant.	ditto	Ditto.		
Fish, parts of	gault	Yorkshire, Isle of Wight; chalk Lyme; green sand, Wiltshire, chalk, Wiltshire, Norfolk, Sussex, &c.	chalk	Paris, Bochum, Aix.

Reptilia.

Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Mososaurus Hoffmanni	chalk	Sussex	....	Maestricht.
Crocodilus, Cuv.	....	....	chalk	Meudon.
Ichthyosaurus, Phil.	gault	Speeton		
Geosaurus	....	....	green sand.	New Jersey.
Plesiosaurus, (Harlan)	....	....	ditto.	Ditto.
Saurocephalus lanceiformis, (Harlan)	....	....	ditto?	Missouri Territory.
Saurodon Leanus (Harlan)	....	....	ditto?	New Jersey.
Chelonia	....	....	ditto.	Maestricht.

General Summary.

Plants	22	species, chiefly marine.
Polyparia	142	52 fibrosa and carnosa, corticifera, 2. 61 cellulifera. 27 lamellifera.
Radiaria	95	
Conchifera	311	99 plagymyona. 123 mesomyona. 17 rudista. 72 brachiopoda.
Mollusca	206	73 gasteropoda. 133 cephalopoda.
Cirripeda	2	
Annulosa	37	
Crustacea	13	
Fishes	7	
Reptiles	8	
	843	species, almost exclusively marine.

Tertiary System.

We have now arrived at the last system of strata deposited in the sea and in lakes; before, as is usually stated, the present races of land animals and plants were called into existence. It is usually stated to be limited as to time between the era of the chalk and the beginning of the modern zoological period; but this definition is something arbitrary in application. As we have seen, on previous occasions, the several systems of strata, however distinct in the great mass, gradually soften into each other at the lines of junction, and sometimes exchange beds, so as to form the whole into a natural and connected series, so it may be with the present set of deposits in relation to the chalk. In England, indeed, as already remarked, this kind of *transition* from the chalk to the tertiaries, is nowhere distinct, nor are we entitled to say decidedly that at any point on the Continent of Europe it is well ascertained.

The blending, however, of tertiary and cretaceous rocks would, if established at many points, occasion no peculiar difficulty in their arrangement, nor alter one just inference drawn from previous observations. It is to be expected from every thing that is known of similar cases, that the great and abrupt change between the chalk and tertiaries in England and in France will be in some other Countries divided into easier gradations, and thus the maxim *natura non facit saltus*, will be found to prevail in this case as in all others.

A greater difficulty however occurs when we attempt to mark the *modern limit* of the tertiary system of strata, arising out of several circumstances important in their history, which scarcely required notice amongst the older deposits.

The ancient systems of strata were almost entirely marine; but

1. The tertiary system includes not only marine, but lacustrine deposits, which sometimes alternate with the marine strata, sometimes appear unconnected with them, and in several instances were evidently altogether independent of them and of each other, being formed separately upon the elevated lands under the influence of the ordinary processes of drainage. Now as similar causes have been in operation long since the tertiary era, and are in operation at present, it is often for this reason very difficult to say what is really the Geological antiquity of a lacustrine deposit, whether it be of the present epoch, or belonging to the tertiary or some intermediate system.

2. Within the tertiary era a variety of land mammalia came into existence which are now extinct, and which it appears had become extinct before what is called the diluvial detritus was scattered, and the elephant and hyæna were destroyed in Northern climes. If instead of antediluvian we should say mastozootic, and instead of tertiary, palæotherian, the generally received inference on this subject is, that the two periods are clearly and distinctly defined. Most of the observations support this view; but in a few cases palæotherian and mastozootic remains occur together, and are supposed to prove that the changes from the earlier to the latter system of organic nature were, like all the preceding, gradually accomplished; that before the palæotheria had become extinct, the ox, mastodon, and rhinoceros had begun to exist.

3. But allowing, for the present, that the palæotherian and mastozootic remains are of different ages, and agreeing by these characters to separate the diluvial from the tertiary deposits; how are we to apply this distinction drawn from the quadrupedal tenants of the land to the marine strata, in which their remains hardly ever occur? Or if, as in England we find quite easy, we should characterise the diluvial deposits by the mode of their occurrence over all the marine strata, what is to be done with strata like the Sicilian tertiaries, which have perhaps no contemporaneous analogue raised above the sea, and are supposed to show no trace of diluvial currents?

4. The tertiary class is often supposed to include only the deposits which happened before the present system of organic nature was established. But do Geologists really admit what these words imply? We who have used these terms, and have come to reflect on their meaning, answer certainly not, either in theory or in practice. For the *present system of organic nature* is most certainly recognised in nearly all the marine tertiary strata, if we trust to the evidence which in every other such case has been thought the best: *viz.* the marine shells. The shells of all the tertiary marine strata are proved by various degrees of evidence to belong to the present *system* of organic nature, for the genera are almost universally the same, though the numerical analogy of the species is very unequal in different deposits.

Neither is it true, that what are called lacustrine tertiaries can in all cases be pronounced to contain exuviæ of another system of organic nature; for if this could hardly be asserted of the basin of Paris, what is to be said of Aix and Œningen?

We come now to the terrestrial accumulation, that is to the diluvial and alluvial aggregates, containing bones of quadrupeds in characteristic abundance, and combining with these the notices of similar remains in lacustrine and marine deposits, the causes of past ambiguity, and the hope of future distinctness appear together. It can hardly be doubted that the land accumulations are capable of being classed by the reliquiæ of land animals which they contain; and this classification gives us the diluvial era, clearly separate both from the more recent and (if there be any remains of such) the more ancient alluvial periods. But this distinction of the races of land animals into periods, applies only to the land, and the extension of this classification to the productions of the sea can only cause utter confusion, and distrust of the inferences to which more legitimate processes would probably conduct us. In a less degree the same confusion will arise from applying this classification to fresh-water deposits, as the mixture of extinct quadrupeda and recent mollusca at Market Weighton in Yorkshire fully proves.

To be consistent, we must certainly allow that the races of land animals might be altogether changed without any corresponding change of lacustrine or marine shells, and we must limit our classifications to their just application. We must judge of the age and other characters of supracretaceous marine strata by comparison with what is known of the modern condition of the sea; the lacustrine deposits of the same era must be compared to the standard of the modern lakes; and the terrestrial accumulations will derive illustration from comparison with the modern state of the land, and the aqueous agencies upon it. In some instances at present, and it is to be expected that hereafter many more will be established, the relative epochs of certain terrestrial, lacustrine, and marine phenomena may be determined, but it is not the less certain that these phenomena

belong to three independent series, which must be studied apart before they can be understood together.

It must be evident from what has been said before that a considerable proportion of the old strata had at the commencement of the tertiary system been raised above the sea, some parts by violent, others by gentle and continued elevation. In the latter way, we imagine, the chalk and oolites of England to have been a little raised above the sea at this period, so as to leave broad planes of the chalk rising gradually from the sea, and, of course, exposed to the violence of its shores, and other parts dry and fit for the growth of plants and the residence of animals. In France the same effects may be supposed to have happened round the greater part of the basin of Paris, while the old granitic rocks of central France, had sometime before raised themselves to nearly their present altitude, and constituted a shore for the oolites and the chalk. The mountains of Brittany, the chains of the Cevennes, the Jura, and the Vosges were also conspicuous in France, while the Black Forest, Odenwald, Harz, Erzgebirge, and Bohemian mountains generally had assumed their present relative heights. Also all the primary tracts of Britain, Scandinavia, Finland, and the Ural had long since circumscribed the ancient sea, or basin of Europe. But as yet the Pyrenees and Apennines, the Alps and Carpathians, had been only partially raised from the deep sea, though enough it would appear to divide the ocean into limited seas, gulfs, and bays, in which the tertiary strata were to be deposited.

This brief sketch will convey a tolerable notion of the observed extent of the tertiary deposits in Europe. The Eastern and South-Eastern parts of England, a large tract round Paris, another equally large area in the South-West of France, detached deposits in the Loire and the Allier, the valley of the Rhone, the valley of the Rhine from Basle to Mayence; the great hollow between the Jura and the Alps, the plains of the Danube and the Po, the subapennine region, many points in Southern Spain, the central basin of Bohemia, these are the tracts at present best known, but they are not the most extensive. From the Ardennes, Harz, Riesengebirge, Carpathians, and Caucasians, great part of the space North-Eastward to the primary rocks of the Oural and Finland is composed of a variable mass of tertiary rocks resting on secondary and primary formations. The Eastern coasts of North America, large areas in Northern Africa and in the region South of the Himalaya, are covered by tertiary rocks.

As far as appears at present, the marine parts of these deposits were formed beneath waters, some of which were connected with the German Ocean, as the Eastern parts of England, the Northern parts of Germany, &c., others with the English Channel and the Atlantic Ocean, as the South of England, Paris, Bourdeaux, and the remainder branched off from the Mediterranean, the Black Sea, the Sea of Azof, the Caspian, &c.

As in the present day the molluscous productions of one sea are distinguishable from those of another, by differing according to latitude and local circumstances, according to the nature of the coasts, influx of rivers, and many other causes, so we may expect the case to have been formerly. This is found to be the fact. The tertiary strata have several common and characteristic features, but they show differences of great importance, both mineralogical and organic, which clearly indicate the difference of circumstances of their production.

We shall first describe the English tertiaries, distinguishing them as marine and lacustrine, and we shall afterwards present a comparative view of the most remarkable contemporaneous foreign deposits.

Tertiary System of England.

The following is a Tabular view of the series of these deposits in England.

		Feet.
Upper marine formation.	Crag, a local marine deposit, consisting of two parts; one a coarse, calcareous, zoophytic, and shelly rock, the other a loose deposit of sand, pebbles, and shells	30 or 40
Lacustrine deposits.....	Enclosing between them an intervening layer of marine, or marino-lacustrine shells, &c.	
Lower marine formation.	Bagshot sand. London clay, with septaria rich in shells. Plastic clay group, consisting of marl covering the chalk, coloured clays, lignites, pebbles, and sand, with shells.	300 to 600

We must here observe, that in the preceding Table there is probably a hiatus between the London clay and the lacustrine deposits in Hampshire, that there is no case where the crag overlies the fresh-water beds, they being found only in separate districts, and that it is also probable that a hiatus exists between the London clay and the crag. Notwithstanding the want of direct sections, comparisons with the tertiary strata of other districts appear to warrant us in classing the crag as a more recent deposit than the lacustrine beds. This will appear in the sequel.

The Lower Marine Formation

consists of two principal groups which are in many cases very distinctly characterised, and always appear to indicate considerable difference in the state of the waters which produced them.

The *plastic clay* group consists, generally, of green, yellow, and white sands, with or without marine shells, layers of rolled flints, occasionally furnishing attachment to oysters, clays and marls of a yellowish or bluish colour with shells, and sometimes of many various tints, and then mostly devoid of shells. Beds of lignite also occur in the sands of this group.

The Map will show with sufficient accuracy the general range of this group from Essex through Buckinghamshire to Reading and Hungerford, and on the North side of the Kingsclere ridge of chalk, to Guildford and Croydon, and through Kent to Chatham, Canterbury, and Deal. South of the Kingsclere and Wealden ridge it ranges above the chalk from Newhaven and Brighton by Chichester near to Arundel and Houghton Hill, and thence to Dorchester, including the pipe-clay of Poole Heath, and turning Eastward again forms a narrow ridge of vertical strata between the chalk and London clay of the Isle of Wight.

The sections of the plastic clay group are usually considered to be very irregular and confused, and so, indeed, they are, and mark, upon the whole, a turbulent period and varying velocities of water. But we believe it possible to arrange these varying sections so as to present a tolerably consistent Tabular view thus:

Plastic clay group.	Upper part, consisting of coloured sands and coloured clays with beds of lignite, and occasional layers of flints.

Plastic clay group.	Middle part consisting of blue clay, or marl, with cerithia and other shells, sometimes alternating with sands, with or without shells.
	Lower part containing green sands often associated with flints and pebbles, and occasionally full of oyster shells, sharks' teeth, &c.

The following section of Loam Pit Hill, near Lewisham in Kent, by Dr. Buckland, will serve to convey a good notion of the general characters of the plastic clay group near London, except that the quantity of rolled pebbles is smaller than usual.

London Clay above.

	Feet.
Alluvium	
Striped sand, yellow, fine, and iron-shot	10
Striped loam and plastic clay, containing a few pyritical casts of shells, and some thin leaves of carbonaceous matter	10
Yellow sand	3
Lead-coloured clay containing impressions of leaves	2
Brownish clay containg cythereæ, estimated at	6
Three thin beds of clay, of which the upper and lower contain cythereæ and the middle oysters	3
Loam and sand, in its upper part cream-coloured, and containing nodules of friable marl, in its lower part sandy and iron-shot	4
Bed of ferruginous sand containing flint pebbles	12
Coarse green sand, containing pebbles	5
Ash-coloured sand, slightly micaceous, without pebbles or shells	35
Green sand identical with the Reading oyster beds, containing green-coated chalk flints but no organic remains	1
Chalk with beds and nodules of black flint	

The green sandy lower part of the group, with or without pebbles, oysters, and other shells, and sharks' teeth, appears to be constant and very characteristic, being found at Sudbury, Reading, Woolwich, &c.; and also occurring in the Isle of Wight.

The blue shelly clays of the middle part are well developed and rich in fossils, (much analogous to those of the London clay,) about Woolwich and other parts of Kent, and attain the monstrous thickness of 200 feet in the Isle of Wight, but they are not so continuous as the green sands. In the New Forest, and at Newhaven, they much resemble the Woolwich beds in their zoological contents.

The upper series of coloured sands, clays, and lignites, arrives at great importance in Hampshire, but is only feebly traceable around London, and appears quite unknown in Essex and Suffolk, and generally on the Northern rise of the chalk from the Vale of the Thames. The pipe clay of Poole in Dorsetshire, which is of white, grey, or blue colour, belongs to this division. It overlays a seam of friable lignite (brown coal) somewhat like Bovey coal.

There are several layers of white pipe clay at Poole Heath, three to five feet each, alternating with black sand, red sand, and brown clay, and covered by white sand. All along the North side of the range of chalk hills which extend from Handfast Point to beyond Corfe Castle, there is an extensive stratum of pipe clay in a horizontal position. It contains a bed of coal exactly resembling that of Alum Bay in the Isle of Wight. (Webster, in *Geology of England*, p. 53.)

The celebrated section of Alum Bay, for which we are indebted to Mr. Webster, exhibits the vertical beds of the plastic clay group of the astonishing thickness of more than 1000 feet.

The series here admits of the same general divisions mentioned above.

Upper part, consisting of 543 feet of highly coloured and variegated pipe clay, white, yellow, grey, and blackish, and alternating even minutely with beautifully coloured sands. Near the middle are three beds of lignite, in which flints and vegetable reliquiæ are observable, and further to the North (nearer the top) are five other beds of the same sort of coal, each a foot thick, under this is a series of coloured and variegated sands 321 feet thick.

Middle part. Dark blue clay 200 feet thick enclosing much green earth, and nodules of a dark argillaceous limestone with shells. (Cytheren, &c.)

Lower part. Green, red, and yellow sand, 60 feet.

The London Clay

is a very simple argillaceous deposit, of considerable but variable thickness, in one place (Wimbledon) exceeding even 530 feet, and in another (High Beech in Essex) 700 feet. It is usually of a lead-grey, or blue colour, but dull brown and red clays occur in it, perhaps most usually in the lower part. Green grains are often observable in it, a few sandy layers occur, and these, usually containing green sand, are indurated at Bognor and Selsea into a considerable rock. Septaria abound in it, and some imperfect laminæ of marly limestone have been noticed. It lies upon the plastic clay group over considerable tracts in Essex, Berks, Hertfordshire, Middlesex, Hampshire, Surrey, and Kent, on the Northern side of the Wealden ridge, borders the Southern coast from Worthing to Hordwell, and separates the coloured sands and clays of the Isle of Wight from the fresh-water deposits above. It is chiefly interesting for the vast number, beauty, and variety of its organic remains, of which the cliffs at Harwich, Sheppey Isle, Hordwell, Stubbington, &c. are rich repositories. Considerable quantities were also obtained in cutting for the Archway at Highgate. Extent and characters.

Having been much exposed to watery action, which it could ill resist, it is often left in insulated hills, upon the substrata of sands and clays. Mineral springs, so common to blue clays, rise in considerable number from the London clay near the metropolis. The most remarkable are those of Epsom, famous for their sulphate of magnesia, Bagnige Wells, and Acton.

It yields little water to the well-sinker, but on being pierced to the sands below, or, as circumstances may require, to the chalk, great streams of water rush up, and may even overflow the surface if the chalk hills which gather and transmit the water be sufficiently elevated. This is the case about London, under which subterranean streams flow from the chalk of Surrey on one side, and that of Hertfordshire on the other.

The London clay possesses all the characters of a very quiet and continuous deposit, perhaps in deep water, yet not far from shore, since a few considerable remains of land and littoral productions occur in it, as wood, turtles, and crocodiles, but no pebbles nor coarse sands.

The temporary turbulence of the plastic clay period had wholly passed away, and only finer sediment in great quantities found its way to the sea. Shells of the most delicate and fragile forms are perfectly uninjured in this clay, except in the rare case of its being laminated.

Bagshot Sand.

We shall place the Bagshot sand described by Mr. Warburton (*Geological Transactions*) above the London clay, on which it rests in the only districts in which

as yet it has been much noticed. Bagshot Heath and Hampstead are the principal localities. Its fossils are few and imperfect, but are thought by Mr. Warburton to resemble some of those found in the upper marine formation of the Paris basin.

Fresh-water Group.

Isle of Wight.

For our knowledge of the fresh-water tertiary strata of England, we are indebted to Mr. Webster. They exist only along the Northern side of the Isle of Wight, and on the opposite coast of Hampshire. After the chalk and older strata, together with the plastic clay and sands and the London clay of the Isle of Wight, were thrown by convulsive movements into positions so extraordinary, the fresh-water strata now to be described were deposited horizontally over the line of this great disturbance. What *interval of time* may have elapsed, or what intermediate Geological phenomena may have occurred between the dislocation of the chalk and marine tertiaries, and the formation of the fresh-water deposits above, cannot be discovered, at least in this situation. It is in the highest degree probable, that very tumultuous deposits must have succeeded the convulsive movements, and it is quite possible that under the fresh-water deposits of Headen Hill others may exist, which, if marine, might render more complete than it is the English series of marine tertiaries.

The fresh-water strata of the Isle of Wight are parted into two minor groups by an intermediate set of layers of light green marl, 36 feet in thickness, containing in extraordinary abundance and great perfection marine shells of the genera potamidum, voluta, fusus, natica, ancilla, cyclas, venus, cytherea, ostrea, &c. These are distinct from the fossils of the London clay. Some species in this bed are decidedly fresh-water mollusca, as neritina-like fluviatilis, and melanopsis. Potamida, which are numerous, appear to indicate an estuary deposit; and it is probable that we may be justified in regarding the whole of this, which is called the upper marine of the Isle of Wight, as a local estuary deposit, caused by some temporary physical change in the region between the eras of the two decidedly lacustrine groups, which it separates.

Crag.

Range and characters.

The most recent of all the marine stratified deposits, is also one of the most irregular. It occurs only in the Eastern part of England over a narrow space of little elevation from the cliffs of Walton in Essex to beyond Aldborough in Suffolk. It is also known to some extent in Norfolk, particularly at Bramerton near Norwich.

In this short course the crag is found to rest on the London clay at Walton and Bawdsey, and on chalk at Bramerton, being evidently a much later deposit than either and wholly independent of them. It exhibits also considerable variation of character. Its general aspect in numerous pits in Suffolk is a ferruginous mass of shells, dark pebbles, and bones and teeth of fishes and reptiles, mixed up in a confused mass of sand, sometimes grouped into beds, and sometimes exhibiting oblique and disordered laminæ, very much resembling the general, character of a modern very shelly beach. And from the manner in which it lies in the country about Ipswich and at Bramerton, there can be little doubt that it is really an ancient beach of the German Ocean. But about Aldborough and Orford the crag assumes a totally different character, becoming, in fact, a zoophytic limestone, an accretionary rock, formed by the cementation of coralline reliquiæ, shells, and calcareous sand, probably after the manner of the Guadaloupe accretionary limestone, and a similar littoral formation on the coast of the Isle of Ascension. This coralline limestone contains some of the most characteristic shells of the ordinary crag, and is clearly of the same era as that heterogeneous deposit.

Shells of the Crag.

The quantity of shells contained in the ordinary pebbly crag of Suffolk is beyond all calculation. The name of crag is, we believe, derived from a British word signifying shell, and the Suffolk pits have been for a long time in work solely to manure the ground with their calcareous exuviæ. The number of species here buried is also very great. Upon comparing them with recent kinds we are presented with very curious and striking results. There are several of the crag shells so exceedingly similar to recent shells of the German Ocean, that it is impossible to distinguish them. Turbo littoreus retains its colour, many others are with difficulty separated by minute discrimination; but some, as the corals of Orford, pecten princeps, terebratula Dalei, and others, are evidently unlike any thing now existing in the German Ocean, and indeed not now to be paralleled in any part of the World. A small number of the crag shells appear very similar to some in the London clay, but in general they have few common analogies, and the most cursory observer must be struck by the total difference of general aspect. The London clay shells recall to our memory the shores of a *Tropical climate*, the crag fossils speak to us of an ancient race of shells of *our own seas*. But the corals are *sui generis*, and upon the whole, those Geologists who are most desirous of uniting the crag deposit to the present system of Nature, must acknowledge that it bears the stamp of an ancient and peculiar era. It has often been stated, that bones of elephant, teeth of mastodon, &c. have been found in the crag. This mistake, as we believe it to be, may have arisen partly from the notion once prevalent, that crag was only a particular kind of diluvial deposit, and partly from attempting to *supply an omission* in Mr. Smith's Work, (*Strata identified*,) in which the tooth of a mastodon is figured from a noble specimen now, with this original collection, deposited in the British Museum, but without mention of locality. It was picked up under the diluvial cliff at Happisburgh, from which so many elephantoidal teeth and bones have fallen into the sea. A very unexpected addition to the list of organic remains of the crag, is the badger, (probably undistinguishable from the common European species,) of which good specimens of the skull and leg bones are in the Yorkshire Museum.

It must evidently be of little use to give sections of such a deposit as the ordinary crag. We shall therefore subjoin only Mr. R. Taylor's account of the Bramerton pit, and mention that, in general its thickness is about 30 feet, and its greatest height above the sea, in Walton Naze, 50 or 60 feet.

	Feet.
1. Sand without organic remains....................	5
2. Gravel....................	1
3. Loamy earth....................	4
4. Red ferruginous sand, containing occasionally hollow ochreous nodules....................	1½
5. Coarse white sand, with a vast number of *crag shells*..	1½

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		Feet.
6.	Gravel with fragments of shells	1½
7.	Brown sand, in which is a seam of minute fragments of shells 6 inches thick	15
8.	Coarse white sand with *crag shells*, similar to No. 5. tellinæ and murices most abundant	3½
9.	Red sand, without organic remains	15
10.	Loamy earth, with large stones and *crag shells*	1
	Total	49
	Large irregular black flints crowded together *in situ* in the chalk. Attached to these flints are echini, terebratulæ, inocerami, and belemnites	1
	Chalk to the bed of the river	15

Foreign Tertiary System.

Under what circumstances deposited.

The disturbances which preceded the deposit of the whole or the greater part of the tertiary strata, were very extensive, and appear to have operated considerable changes in the configuration of the land, and to have left the European seas, certainly expanded much beyond their present limits, but yet pretty evidently related to the present depths of the Atlantic, Baltic, and Mediterranean. It has long been the custom to speak of tertiary strata as being particularly deposited in *basins;* an inaccurate use of this term, for the tertiary strata are not more, nor perhaps so much, separated into basins as many of the older strata. We recognise, indeed, in them a greater local diversity, such as at present obtains, both with respect to the materials deposited and the organic remains entombed, in separate branches of the same sea, or at distant and dissimilar parts of the same coast. The true way of considering the tertiary strata is, to view them as the varied deposits of one long period, produced chiefly in branches of one great ocean, variously divided by the elevated lands. Some particular deposits may perhaps be best explained by allowing the existence of mediterranean seas, or even salt-water lakes. Cases in which fresh-water and marine shells alternate must be examined upon their own evidence, to learn whether such alternations were produced in a lake, or at an estuary; and finally, the true fresh-water strata of the tertiary period must be separately treated, having such relations to the marine tertiary accumulations as the fresh-water formations of the present day have to the deposits now in progress below the sea. Thus we shall have purely marine strata, marino-fluviatile, or marino-lacustrine strata, and lacustrine strata, all referable to the tertiary period, the relative eras of which can sometimes be correctly *determined*, sometimes satisfactorily *inferred*, and in other cases only *conjectured*.

The relative age of strata which were deposited in the same branch of the sea, can be *determined* by observation, even though subsequent convulsions may since have separated the deposit into detached portions, as for instance the Hampshire and the London marine tertiaries. It can be *inferred* satisfactorily, even for originally distant deposits, when large suites of organic remains, not differing more than we may expect to happen in such cases, concur with a general analogy of Geological position; and in this case, the inference is the stronger, if the data analyzed and referred in portions to successive periods, apply in a similar manner to the two localities.

The mineralogical character of the deposits is of importance in proportion as the deposits happened in the same branch of the sea, along the same line of coast, parallel to the same range of mountains, or to similar ranges of analogous rocks. In short, tertiary strata may be expected to show close agreement, considerable resemblance or general analogy, according to the local circumstances of their production, and it is perfectly consistent with Geological experience and sound theory, that the clay of London, the calcaire grossier of Paris, and the lower subapennine marls, may be exactly contemporaneous deposits, deriving their peculiar character from the peculiar circumstances of their localities. If we do not so often find in the older systems of strata these great mineralogical contrasts between exactly contemporaneous strata, we must remember that the circumstances of land and sea, when the earlier deposits happened, were more uniform, and that by a long succession of convulsions the tertiary sea was made to flow round islands and promontories, containing a vast variety of rocks, reared in deep or shallow waters, and exposed in various degrees to the processes of disintegration.

We may venture by the aid of what is known of the effect of former convulsions, and the help of the characters furnished by the newer strata, to describe the hydrography of the great European Sea in which tertiary strata were accumulated.

Extent of the tertiary Sea of Europe, &c.

It may perhaps be described as an immense inland sea, bounded on the West by a broken line of elevated land in Spain, Auvergne, Brittany, England, Scotland; on the North by the Scandinavian peninsula, Finland; on the East by part of Russia, the Oural, the mountain circle which encloses the Aral, the Caspian and the Black Sea, and a line prolonged through Syria toward the Red Sea; on the South by a line including the present Mediterranean, part of the Libyan Sands, and Egypt. This ancient Mediterranean appears to have been connected with the Bay of Biscay and the Atlantic by shallow channels between Angers and Poitiers, and by the line of the Canal of Languedoc. It embraced the North Sea, and so probably communicated with the Northern Ocean, included a part of the Baltic, and was open to the Indian Ocean through the Red Sea.

In this vast area rose at that time irregular tracts of land, forming upon the whole two islands. The Northern island, stretching in a sweep from the Cevennes to the Carpathians, and including the great plateau of central France, the Jura, Vosges, Schwartzwald, Ardennes, Taunus, Westerwald, Teutoburger Wald, Harz, Erzgebirge, the circle of Bohemian and Moravian mountains, and the long range of the Carpathians. In the Southern island, rose in partial peaks, and with small surface, the Alps of that epoch, connecting themselves with the Apennines and the mountains of Dalmatia, Croatia, and Greece. The ancient Sea of Bohemia and the Sea of the Rheinland were entirely or nearly surrounded by land; the Seas of Swisserland and Hungary expanded into the Black Sea, and contracted their waters into a narrow channel along the line of the Rhone, there to unite with the Mediterranean; and the basin of Paris appears to have been only partially connected by shallow channels with the North Sea or the Bay of Biscay.

Its relation to the existing Seas.

Viewed then in connection with existing Seas, we may consider the inland tertiary Sea in several portions.

1. The arms and branches of the Mediterranean, stretching up the extended Gulf of Lyons, the Sea of Swisserland and Hungary and the extended Adriatic Gulf, washing the Eastern part of Spain, Libya, and Egypt, and joining the Red Sea.
2. The dependencies of the Atlantic and North Sea, as the Bourdeaux basin, which was also connected with the Mediterranean, the basin of Paris, the great Sea of England, and the Netherlands. To these may be joined the area of Northern Germany, Russia, and the Countries bordering on the Black

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Sea and the Caspian. We might perhaps be justified in making a separate division for the latter surfaces, could we appeal to any satisfactory account of the organic reliquiæ of Countries which as yet are very imperfectly known.

For comparison with the English series, we shall first take the example afforded by the basin of Paris, so admirably described by Brongniart and Cuvier, and on that account frequently appealed to as the general type of tertiary formations.

Following the general classification of Messrs Brongniart and Cuvier, we shall divide the Parisian marino-lacustrine strata into five groups, in the order of their eras.

5. Upper fresh-water or epilimnic group.
4. Upper marine (sands and marls.)
3. Lower fresh-water or palæotherian group.
2. Lower marine (calcaire grossier.)
1. Plastic clay group, lately subdivided by M. Brongniart into three groups. (*Tableau des Terrains.*)

Plastic c[lay] gr[oup].

Our remarks on these deposits will be as concise as the great interest attached to a right understanding of the mode of their formation will allow. The idea we formed to ourselves from a consideration of the plastic clay group of England, was that of a varied series of deposits, consequent upon some considerable convulsions, partly derived from the waste of the cretaceous system, and accumulated in a sort of estuary of that system. Pebbles and sands, with or without shells in confusion, a few bands of clay with shells, and beds of lignite, layers of pipe clay, and plastic clay, lying in sand, compose the rather heterogeneous group, which ends upwards with the abundant tranquil deposit of London clay.

On the great scale, the plastic clay group of the basin of Paris presents very analogous characters. It rests on the irregular and worn surface of the chalk, contains accumulations of pebbles, beds of lignite, layers of coloured plastic clay, and by occasionally including beds of calcaire grossier, analogous to the shelly layers of the English group, appears to leave hardly any important point of resemblance unsatisfied. On a careful review, however, some differences arise. The order of succession of the several parts is not exactly similar. The French series taken generally may be thus expressed.*

Upper part consisting of potter's clay, marls, sands, and much lignite, the clay containing many lacustrine shells, as cyrenæ and melanopsides, alternating with a few marine shells, as ostreæ and cerithiæ; the lignites containing remains of mammalia and fresh-water reptiles.

Middle part or plastic clay and sands, sometimes alternating, the former generally beneath, of very uncertain thickness, indistinctly stratified and devoid of shells.

Lower part very local, consisting of fragments of chalk, flints, &c.

These deposits are very unequally spread in the basin of Paris, and the lignite with shelly clays and marls belongs principally to the vicinity of Soissons. We may draw the following inferences. (1.) That the convulsive movements which wasted the chalk of England, and raised its originally deep strata to a littoral and estuary situation, were also experienced in the basin of Paris. (2.) That in this estuary irregular deposits happened, both marine and fresh water, the latter prevailing in particular places more than in the corresponding basins of England, and recognised by distinct layers of fluviatile mollusca, sometimes alternating with deposits containing a few marine shells. The basin of Paris seems therefore to have been at first an estuary, admitting into it considerable currents of fresh water from rivers or lakes, containing shells, crocodiles, and turtles, and transporting vegetables; but the deposits were generally more tranquil than the contemporaneous products of England.

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The "*lower marine*" *group*, or calcaire grossier, and its coeval and associated sandstones, form the principal and characteristic rock of the Paris basin, in which the vast number of marine shells occur. The calcaire grossier is a granular, sedimentary, sandy, yellowish-white limestone, of considerable thickness, regularly bedded and jointed, with partings of a marly nature, including occasional beds of sand, and in some cases lignite and marls. The lowest part of the rock is usually filled with green silicate of iron, and can hardly be distinguished from some kinds of marly green sand. It contains hardly the least trace of metallic substances, but encloses a few beds of hornstone, some cubic fluor, quartz, and calcareous spar. It is the building stone of Paris. In some parts, it is replaced by a developement of sandy beds, which often exhibit glistening fractures. Pebbles lie in it, chiefly at the top and the bottom. Upwards of 1500 species of marine shells belong to this group, and only a very few land or fresh-water species, rarely brought down with vegetables, diversify the character of the deposit. A great proportion of the shells of the London clay are recognised among the more numerous reliquiæ of the Paris basin.

The lignite and marls occasionally included near the top of the calcaire grossier, (Brongniart,) remind us that the action of the fresh waters, though nearly unobserved during this long period of the deposition of the calcaire grossier in quiet sea, might easily be recalled to the basin of Paris by a change of local circumstances.

Such a change occurring, a part of the basin of Paris was surrendered for a time to the undisputed possession of fresh water, and the following group was deposited.

Palæotherian or lower fresh-water group.

The palæotherian, or lower fresh-water group, is principally, says M. Brongniart, a chemical deposit from water, or at least this mode of origin is very frequently to be traced in it. Coarse mechanical aggregates, the result of violent currents, are unknown in it; while gypsum, siliceous nodules, and agates are frequent, and sulphate of strontita, carbonate of lime, and silicate of magnesia occur in the marls which compose a large part of the mass of the formation. But it is from the remains of terrestrial and fresh-water plants, and the exuviæ of land and fresh-water animals, that this group of strata receives its most exact as well as most interesting characters. In the interior of its mass no marine bodies of any kind have been found, but several plants and shells of the land and fresh water, generically identical with existing tribes, as well as land quadrupeds belonging to genera now extinct. The study of these quadrupeds, first awakened in Cuvier that indefatigable zeal in the examination of fossil animals, which has established the permanent union of the highest branches of Geology and Zoology.

Argillaceous and calcareous marls with limnææ, frequently alternating in very thin laminæ, (a common character of lacustrine deposits of all ages,) constitute the mass of this palæotherian group; gypsum in broad crystallized masses, of a vertically prismatic structure,

* Mr. Chantrey, whose unrivalled eminence in his profession is united with very extensive and accurate information on other subjects, has observed in the interior of plaster casts of large statues, which had been subjected to a drying heat of 350°, an irregularly prismatic structure, comparable to that of the gypsum of Montmartre.

not stratified, is frequently associated with them, as in the basin of Paris, at Puy en Velay, and at Aix en Provence, silicious limestone locally diversifies them, and yields agates, menilites, nectic quartz, &c. To this group M. Brongniart also refers the lignites which lie in the molasse of Swisserland. The quadrupedal reliquiæ are, perhaps exclusively, found in the gypsum, and few other organic bodies accompany them.

This evidently fresh-water group occurs in many parts of France, sometimes, as in Auvergne and Cantal, without the least trace of a genuine marine tertiary basis. About Montpellier it is found in combination with marine deposits nearly as in the Paris basin, and there appears good reason to believe that the causes which repelled the sea from that basin were extensively at work in other parts of Europe. This indeed is not a very difficult part of the problem. The expulsion of the sea may easily be imagined to have happened by the elevation of new land, or by a great local dislocation, such as we know to have often occurred; and thus a fresh-water deposit in the basin of Paris might be laid on a basis of immediately antecedent marine tertiary strata, at the same epoch that in other parts of France elevated above the sea before the tertiary period, these deposits were laid on any of the older rocks. From the estuary or lake which we now call the basin of Paris, to the mountains of Auvergne, there might be formed, contemporaneously, (that is, in a given Geological period,) many fresh-water deposits of varying character, under varying conditions, which are to be ascertained by special investigation of each case. But after the completion of this lower fresh-water deposit, subterranean movements brought back the sea into the basins of Paris and Montpellier, at the same time that marine exuviæ were introduced into the basin of Hampshire. It does not follow, as a necessary inference from the data before us, that this subterranean movement was centred below the basins of Paris, Montpellier, and Hampshire, nor that these basins were raised or lowered at all; it is only certain that subterranean movements must have occurred in such a manner as to interrupt and restore at intervals the connection of these districts with the ancient sea. In what respect is this different from the case of the Weald of Sussex and the ancient coal basin of Yorkshire?

Upper marine group.

The "*upper marine*" *group*, produced in the basin of Paris by the marine irruption which covered the palæotherian gypseous marls, is composed chiefly of sands of many colours, occasionally indurated to stone, with fewer shells than in the lower marine group. The base of the group is, at Montmartre, a mass of calcareo-argillaceous marls, greatly analogous to those of the fresh-water group below, a gradation of character very much to be expected; conglomerates lie on the coloured sands in the Northern and Eastern parts of the Paris basin. A sandy, shelly limestone containing bones of the palæotherian, and also of the subsequent diluvian era, called *calcaire moellon* by M. de Serres, abounds at Montpellier and Narbonne. The molasse of Swisserland, a very complex and disturbed deposit, is referred to this era.

Upper fresh-water group (Epilimnic) group.

The parallel between the three basins of Hampshire, Paris, and the South of France, is drawn still closer by the occurrence in all three of "upper fresh-water" beds, the last usually included in the tertiary strata. It must in some cases be doubtful whether the upper fresh-water deposit recognised in a tertiary district be of the antiquity of this Parisian epilimnic group, and it is highly probable that lacustrine deposits will be found of all intermediate ages from the date of the uppermost tertiaries of the Paris basin to the deposits of the modern era. Such, perhaps, are the lacustrine groups of Œningen and Georgesgemund, which have become better known to the English reader in consequence of Mr. Murchison's descriptions. But, in the case of the localities mentioned above, this doubt is not to be entertained. The most characteristic rock of this group in the basin of Paris is the millstone, a silicious rock full of cells and tubular sinuosities, attributed to the extrication of gas from the bed of the lake, as is known to happen in ordinary cases, and some fresh-water shells and seeds of chara. (Gyrogonites.) In other districts, especially in Italy, a marly limestone, analogous to the travertino which is daily formed there by carbonated springs, is considered by Brongniart the representative of this group, but it is obvious that this tufaceous deposit may be of all ages. The upper fresh-water deposit, with, probably, other recent deposits of the same nature, is recognised in Auvergne and Cantal, on the Loire, Allier, and Cher, in the Department of Gard, in Swisserland, Austria, and Hungary.

Faluns of Touraine.

To these characters of the strata in the Paris basin, described by MM. Brongniart and Cuvier, must be added a notice of a set of gravelly sands in the Faluns of Touraine, long celebrated for abundance of shells and other organic remains, but which were first examined with attention by M. J. Desnoyers. Along the line of the Loire valley at several points, as well as at Rennes, shelly and gravelly deposits occur, which, from Desnoyers's investigation, appear certainly to be of posterior date to the whole Parisian formation, and to contain not only a variety of shells and corals distinct for the most part from those of the Parisian tertiaries, but also a mixture of quadrupedal remains, both of the palæotherian and mastozootic era. Besides palæotherium, lophiodon, and a species of anthracotherium, which would generally be referred to the era of lacustrine tertiaries, there are bones of mastodon, hippopotamus, rhinoceros, tapir, horse, and deer. These, the most recent, probably, of all the deposits connected with the Parisian series, are compared by M. Desnoyers with the English crag; but the propriety of this reference is denied by Mr. Lyell, on the ground that their suites of organic remains have not the same ratio of analogy to existing tribes; the resemblance of the deposits is, however, remarkable. Thus a sequence of tertiary deposits of the same general characters appears to be clearly ascertained in the Southern parts of England and the Northern parts of France, and the beds in the two localities are of the same, or nearly the same age. This series has three principal marine terms, of which the lower one (London clay in England, calcaire grossier in France) is very continuous and the most important, the middle one is variable, and the upper one local and littoral, perhaps, we may add, of rather uncertain date. The series contains also two lacustrine terms, and one, the lowest of all, a product of transient convulsions consequent on the rise of the chalk strata.

This agreement is very interesting. Yet it is not to be thought that in other parts of Europe, which are not subjected to the same repeated convulsions, a similar sequence of marine with similar interpolations of lacustrine deposits should often be met with. On the contrary, it ought to be expected that when the tertiary deposits are wholly marine, the triple character, which

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in France and England they derive from definite periods of convulsion, should be confounded into a general series of many graduated or alternating terms, as happens to the oolitic and other extended marine systems. The further descriptions of tertiary strata, introduced for comparison with those of England, will be divided into marine and lacustrine; the former will be first noticed.

South of France

The tertiary strata of the South of France are generally coeval with those of Paris, and the greatest assemblage of shells and other marine remains lies in sandy and subcalcareous beds, thought by M. Brongniart to be of the same age as the interlacustrine sands of Paris. In the districts of Bourdeaux and Dax, 600 species of shells have been collected from these strata, which Mr. Lyell (vol. iii) arranges in four divisions thus:—

4. Siliceous sand without shells.
3. Gravel.
2. Sand and marl with shells.
1. Blue marl with shells, sometimes 200 feet thick.

Below all these calcareous strata occur with shells of the Paris basin.

M. de Serres has shown the much greater accordance which the Bourdeaux and Montpellier shells bear to those of the subapennine formation of Italy than to the strata of the basin of Paris, and it is from comparison of the organic remains that Mr. Lyell ranks together the Bourdeaux and Touraine shells, and puts them above all the Parisian beds. It is desirable to attain an accordance of opinion in the relative age of these strata, because they furnish common ground of comparison for the deposits which border the Apennines, the Alps, and the Carpathians.

North of the Alps.

The most complete section of tertiary strata along the Alps has been furnished by the researches of Murchison and Sedgwick in Lower Styria.

Uppermost group, calcareo-arenaceous.	Calcareous sands and pebble beds, calcareous grits and oolitic limestones, containing many shells, some of these of existing species.
	White and blue marl, calcareous grit, white marlstone, and concretionary white limestone with shells.
Middle group, calcareous.	Below this is a coralline limestone, with shells, in one place 400 feet thick, associated with marls
Lowest group observed.	Conglomerate with micaceo-calcareous sand, and millstone conglomerate.
	Blue marly shale and sand, with shells analogous to those of the calcaire grossier and London clay.
	Shale and sandstone with beds of lignite, accompanied by fluviatile and terrestrial exuviæ.
	Conglomerates, grits, and micaceous sandstones.

The coralline limestone here mentioned serves as a good line to connect the sections along the line of the Carpathians. At Vienna, Murchison and Sedgwick give the following series:—

Alluvial beds? of löss and gravel, the latter containing bones of mastodon, tapir, anthracotherium, &c.
Fresh-water limestone.
Leithakalk or coralline limestone and calcareous conglomerate.

Lower group	Upper blue marls and sands, very rich in shells, yellow sand and shells.
	Lower blue marls 300 feet, compared to London clay.

Transylvania, &c.

In Transylvania, Boué gives the series thus:—

Upper group shelly sands, marine and fresh water.
Sandy coarse limestone, equivalent of the Leithakalk.
Molasse.
Clay and marls blue and yellow.

And this applies to Moravia and the West of Hungary, where the lower beds are inclined toward the Carpathians.

Gosau beds.

Below all these tertiary strata, in Geological position, but raised to a great height in the Alpine region by powerful dislocations, occur those shelly marls and sands with conglomerates and traces of lignite, which have acquired celebrity from the researches of Murchison, Sedgwick, Boué, Von Lilienbach, and other Geologists. The discussions on their relative age are yet unsettled, because no sections can be obtained, under the difficult circumstances of the case, which put in a clear order of uninterrupted succession the whole mass of tertiaries, or allow a very confident deduction concerning the relation of all the parts taken separately. The obscurity of the subject is increased by the admitted indistinctness and variation of mineralogical character in the tertiary sands and conglomerates of the plains of the Danube. Yet it is not to be supposed that no inferences can be grounded on the laborious investigations of the eminent Geologists above named. The Gosau shelly beds are limited below by the Alpine limestone at Gosau, and in the Reutersberg by the same limestone, (hippuritic,) covered by grey or reddish marls and marlstone containing a few fossils of the chalk formation: above, these beds are known to pass under the molasses of the plains North of the Alps. Two sections, derived from the labours of Murchison and Sedgwick, will, with this understanding, sufficiently show the nature of the beds. The first is across the Valley of Gosau.

Uppermost group.	Red and green slaty micaceous sandstone several hundred feet thick. (Cap of the Horn.)
Second group	Green micaceous gritty sandstone, extensively quarried as whet-stone, succeeded by yellowish sandy marls. (In the Ressenberg.)
Third group	Vast shelly series of blue marls, alternating with compact limestone and calcareous grit; traces of vegetables above, abundance of shells and corals in the middle and lower part. (In the Valley of Gosau.)
Lowest group.....	The above series gradually changes to beds of a more conglomerate character, which pass into red sandstone and marl containing gypsum; a coarse conglomerate, forming the base of the whole system, rests upon and *abuts against* the Alpine limestone. (Russbach.)

The discontinuity between the lowest part of this section and the top of the Alpine limestone is partially remedied in the Untersberg, where a series of four terms likewise appears.

Uppermost group.	A great succession of alternating masses of bluish micaceous marl, slate, clay, sandstone, and conglomerate. Some of these marls contain beds of gypsum and fossils resembling the suite of Gosau.
Second group	Beds of blue micaceous slate clay, and greenish micaceous sandstone.
Third group......	Sandy micaceous marls, alternating with conglomerates, and micaceous calc grit with nummulites. Subordinate to this system are red and variegated marls with gypsum.
Lowest group	A great deposit of marl and marlstone, generally of a grey but in some places of a red colour; containing a few fossils resembling those of the chalk formation.

These beds are conformed in declination to the Alpine limestones of the Untersberg.

Age of the Gosau beds.

The question lately discussed respects the age of these Gosau beds. Messrs. Murchison and Sedgwick conceive them to be the lowest of the tertiary series of the Country, and to have so much analogy to the system

below as to be properly regarded as one of the connecting links of the cretaceous and tertiary rocks. M. Boué ranks them with the green sand system. On appealing to the organic remains, we learn that the affinity of *genera*, and the proportion of univalves and bivalves, bring the Gosau beds to a tertiary type; an examination of the *species* leads M. Deshayes to declare, (Lyell, vol. iii. p. 327.) that none of the Gosau shells are found in any recognised tertiary stratum, but that some of the most characteristic species of Gosau occur in the green sand below the chalk at Mons in Belgium. His researches have led him besides to the following decisive general statement, that no shell has yet been found which is common both to tertiary and secondary strata! Our own impression on the subject, derived from comparing the statements of those eminent writers who have enjoyed the fullest advantages of original examination, can be of no importance on either side; it will be more useful to set an example, unfortunately rare in such discussions, of deliberate indecision, and to appeal to future discoveries. Two remarks, however, must not be omitted. Though all the instances upon record should be found strictly to agree, (even when modified by further discoveries,) with that valuable and practical conclusion for which Geology is indebted to Deshayes, yet this conclusion is general, not universal, and cannot be employed to predicate the result of any new investigations. And again, though certain genera may not yet have been recognised among secondary strata, the deduction of the age of the Gosau beds from this source is of the same conditional character.

Molasse.

The primary and secondary Swiss mountains are bordered on the North by a vast thickness of conglomerates, sands, calciferous grits, and lignites with mammiferous quadrupeds. These are referred by Brongniart to the interlacustrine marine beds of Paris, but the shells as yet found in it are few. M. Studer, of Berne, has amply described this immense and disturbed deposit.

Subapennine deposits.

The subapennine strata are all that remain to be noticed in these comparative sections. No one since Brocchi has been more successful in the examination of these strata than Mr. Lyell, and they furnish much of the evidence which supports his classification of the tertiary system into eocene, meiocene, and pleiocene formations according to the degree of analogy which the organic fossils of those groups bear to existing races of marine animals.* They are of enormous thickness, (several thousand feet,) and must have required very long periods for their accumulation in the Mediterranean, from which they have been uplifted to considerable elevations on each side of the secondary Apennine ridges. The mass consists of innumerable alternations of calcareous and argillaceous marl, light brown, or blue, but the variation of mineral character is slight through the whole series, and not at all sufficient to furnish permanent marks of separation into groups. It is altogether like the sediment which we may suppose to be quietly deposited on the bed of the Mediterranean, by rivers which have left their coarser detritus inland. Beds of lignite are sometimes interstratified, as at Medesano near Parma; subordinate beds of gypsum interstratified with shelly marls and sand also occur in the Parmesan. Sandstone is also interstratified, and rarely compact limestone replaces a portion of the calcareous marls. The whole is covered in places, and unequally, by a coarse yellow sand and conglomerate, in which alternations of fluviatile and marine exuviæ are traceable, and other circumstances are observed which mark estuary or littoral action.

This may be taken as the character of the *middle* subapennine formation. The tertiary strata in the hill called the Superga, in Piedmont, have been described by M. Brongniart and other writers, and from personal examination with Mr. Murchison, Mr. Lyell has inferred that they are the *oldest* part of the tertiary system in Italy. Fine green sand and marl, and a subjacent conglomerate, (the boulders being of primary rocks,) compose these strata, which dip at the extreme angle of 70°, under the more horizontal bluish subapennine marls of the plains of the Tanaro.

Sicilian deposits.

The most *recent* portion of the subapennine deposits is exemplified by Mr. Lyell in the tufaceous formations of Naples, the calcareous strata of Otranto, and probably the greater part of the tertiary beds of Calabria. But the most satisfactory view of the newest tertiary strata, is obtained in the Val di Noto, Sicily. Since Dr. Daubeny's account of that island, the phenomena of its stratified rocks have excited much attention, and Mr. Lyell has been eminently successful in deriving from them important inferences concerning the relative ages and periods of elevation of submarine strata. The following is an abstract of his descriptions.

The whole series of strata in the Val di Noto is divisible into three principal groups.

The uppermost group consists of limestone, sometimes 700 or 800 feet thick, often corresponding in mineral character with the calcaire grossier of Paris, but often more compact. It is regularly stratified and cavernous. These characters, however, are liable to vary in different parts of the island; near Noto it has the concretionary spheroidal structure of the form of the Italian travertino, and contains terrestrial vegetables. These strata prevail not only in the Val di Noto, but, as Dr. Daubeny stated, cap the hill of Castrogiovanni, 3000 feet above the strata. The organic remains of this limestone (generally casts) belong, with hardly any exception, to existing species.

The middle group, not abruptly distinguished from the upper one, consists of white calcareous sand, sometimes with a tendency to oolitic and pisolitic texture, such as the travertino of Tivoli; at Floridia near Syracuse, it changes to conglomerate with calcareous pebbles, associated with sandy limestone full of broken shells. In some parts of Sicily, this group seems to be represented by yellow sand, exactly resembling that superimposed in the blue subapennine marls of Italy.

The lowest of the three groups consists of an argillaceous deposit of variable thickness, called *creta* in Sicily. It resembles the blue marl of the subapennines, and encloses shells and corals in a beautiful state of preservation. The shells belong, with few exceptions, to recent species.

Other marly strata, probably tertiary, occur below, with gypsum, sulphur, and salt.

Relative Antiquity of Tertiary Deposits.

Sufficient data have now been stated concerning the local characters of tertiary deposits to show how variable are the strata of this series, and what great difficulties oppose themselves to a satisfactory classification of them

* These terms are derived from καινὸς, (recent,) combined with ἠὼς, (the dawn,) μείων, (less,) and πλείων, (more.)

according to their relative antiquity. The methods of inquiry which have been found so successful in the solution of that problem, when applied to secondary strata, are here much less applicable. The mineral character of these deposits is, far more than amongst secondary strata, dependent on the nature of the neighbouring mountains of older rocks, on the condition of the sea, and the state of elevation of the land. No two separate tertiary districts, unless perhaps those which follow the line of the Danube, could be satisfactorily compared by mineral characters alone.

The thickness of the deposits is enormously unequal, and the angles of their inclination and their elevation above the sea afford no resting place in this research. Some help may ultimately arise from the theory of elevation of mountains; but M. de Beaumont's view, which alone seems to apply itself distinctly to this subject, is as yet too embarrassed with objections, and too little examined in detail, to be available.

...al ...geal

Nothing then remains on which to build hopes of arranging the tertiary series in a regular sequence according to their ages, but the evidence of their organic contents, and accordingly it is in this direction that the efforts of modern Geologists and Naturalists are vigorously exerted.

This being our only probable basis of operations, it will be well to examine its weak points beforehand, lest much labour be lavished on a fruitless undertaking. Difficulties of a very serious nature, and problems not yet solved, nor even entertained by Geologists, perplex the history of tertiary organic remains.

Mode of employing it in relation to older rocks.

Amongst the older rocks, notwithstanding the general admission of Mr. Smith's views, the organic remains have been chiefly used in reasonings on the condition of the land and sea at certain periods, defined, not by the existence of these organic remains, but by the occurrence of a given sequence of rocks, in which those remains are imbedded. It is true that the classification by superposition has been found wonderfully accordant with the general Geological results of Zoology, but the real dependence of both the practical and the theoretical Geologist is upon the order of superposition. Thus, when the oolitic system is from any cause obscured, the ranges of chalk above and red sandstone below are immediately appealed to. It is true that in such a case the organic remains might very probably equally decide the doubt; but so long as the relation between the organic remains and the strata is known only in its most general terms, and for a whole series of rocks taken together, while the particular modifications of this relation, which should enable us to apply the theory to different strata in a given region, and to the same or different strata in different regions, are yet matter of investigation, it is evident that no Geologist will consider conclusions depending on organic remains alone as having more than half the force of those which combine also the data of superposition. Their use, in short, so far as relates to this question, *viz.* the relative antiquity of deposits, has ever been *supplementary, not principal.* But now we are to take them as our chief guides.

Among the older rocks, such an inquiry, conducted upon the evidence of organic remains alone, would have this advantage, the top of the series to be divided can be clearly defined in the vicinity, though the division may be arbitrary, and so of the base; but in tertiary strata the base can hardly ever be seen, or even safely presumed to be at all known, so many have been the dislocations preceding them, and so abrupt is their junction with the older strata; neither can their uppermost terms be often assigned from a neighbouring type, because the sea, whose bed is the uppermost term, has long since quitted the vicinity of the deposits.

While considering the organic remains of secondary strata, the most successful analogies have always been established by referring to the nearest well known type, whether the object was to compare the fossils of identical or of different strata. Thus the fossils of Normandy present stronger analogies to those of the South of England than to those of Yorkshire; the chalk of England and France produce a greater number of similar fossils than is common to the chalk of England and Sweden, &c. Also the true relation of the oolitic to the lias fossils is best deduced by comparing them in the same district: the oolite of Dundry should be compared with the lias of Bath, rather than with the lias of Yorkshire or of the Western Islands.

These truths are plain, but not unimportant. They lead directly to a particular mode of prosecuting the investigation. For the identification of strata in distant deposits, we must compare them by intermediate terms; for the determining of the relative antiquity of deposits, we must compare, if possible, the marine or fluviatile organic remains which they contain with both the uppermost and lowermost terms of the series, as they occur in the vicinity. Now the uppermost term of this series is certainly no other than the productions of the neighbouring sea and lakes; but the lowermost term is unknown, for the cretaceous system holds no tertiary fossils. We must therefore *assume* the lowest term, and because of the great number of fossils which have been discovered in the calcaire grossier of Paris, this, the lowest really marine deposit of that region, may be chosen as such. If any strata should hereafter be discovered below this stratum and above the chalk, their relative antiquity may be investigated upon the same principles, but the calcaire grossier will in such a case become the upper term, and perhaps the chalk the lower one. Whenever the inquiry can be prosecuted in agreement with these conditions, and the number of organic remains is considerable, the result may be trusted. The organic remains of terrestrial animals can be useful only in comparing terrestrial deposits, lacustrine animals for fresh-water deposits, and marine animals alone must be compared for marine deposits.

Proper mode of employing it for tertiary strata.

As a general upper term of the tertiary series, we are reduced to take the catalogue of existing marine productions, and we are compelled to reason on this, though in fact, through the uplifting of the bed of the sea in some parts, whole races of shells which were then peculiarly situated, (as, for example, a great number of shells in the Mediterranean and in the German Ocean now are,) were probably destroyed within a short period. In such a case the comparison of the fossils is made with a general catalogue indeed, but one from which many of their peculiar analogues have long since been erased, not by gradual change from general physical causes, but by local events.

May we not apply this general argument to the case of the Vienna basin, as compared with the subapennine formations? Is not the former a whole desiccated gulf, and the latter only the dried margin of a gulf? And should we not in this case find the analogy of the fossil and recent tribes strong in Italy, and much fainter in

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the valley of the Danube, even though the deposits were of exactly the same age?

Again, if we were to abstract from the catalogue of living shells with which we compare the crag of England, the shells of the Northern European Ocean, what would be the effect upon the numerical results of this comparison? Instead of forty species in a hundred now identical with living forms, there would remain two; and the crag would appear as little related to the existing Fauna of the *general ocean* as the London clay, which yet is very much more ancient, and, tried by the test of the neighbouring Fauna, appears to be so.

Lastly, it is to be noticed, that even when both the upper term and the lower term of the series is given from a neighbouring type, the application of the principle of the numerical analogy of species to a variety of basins, for the purpose of ascertaining the relative antiquity of distant deposits, demands the admission that the variation of species, on whatever causes this effect depended, has been proportional always, and in all situations, to the time elapsed. Should this be granted unreservedly, without evidence or examination?

Such are a few of the difficulties in the way of determining, by comparison of organic remains with existing forms, the relative ages of the tertiary strata, and we are not aware that this open statement of them should incur the charge of inconsiderate objection. Long experience has proved to us the inestimable value of the legitimate deductions from the study of organic remains with reference to their antiquity; and it is not to check, but to secure the advances of Geologists in this the only avenue to the classification of tertiary strata, that the unknown conditions of the problem are thus pressed upon their attention.

Mr. Deshayes's investigations.

Were the data upon which the further prosecution of this subject depends not more accurate than these which have been accumulated for the secondary rocks, the determination of the age of tertiary strata in distant basins, with such preliminary difficulties in the general reasoning, must have been indefinitely postponed. But, from various causes, the characters of tertiary shells have been long and carefully studied, and the determination of their species, in consequence of their great number, perfect conservation, and decided general similitude to recent kinds, has been successfully attempted by Lamarck, Brocchi, Sowerby, and other Conchologists. But it is to Deshayes that the Science owes the most lasting obligations of this nature. From the most extended examination of shells both recent and fossil ever attempted, that eminent Conchologist has deduced the most valuable and consistent results which Geology has yet received from any Naturalist, on the subject of the geographical distribution of fossil species, and the numerical ratio of identity between fossil and recent tribes. The Tables which he has constructed from this laborious investigation are given at length in Lyell's *Principles of Geology*, vol. iii.

The order of deductions in these pages being to a certain degree different, we shall not copy those Tables, nor even the results in the way they are given, yet all the statements to be made here are based entirely on the data of Deshayes. For the sake of a common scale, ratios to one hundred will be introduced when useful. Land and fresh-water species are included, but ultimately, no doubt, they will be separated from the Tables of marine shells.

The number of recent species examined by M. Deshayes, for the construction of his Tables, is 4780; of fossil species 3036; together 7816; but 426 of these were both recent and fossil; therefore the whole number of distinct species examined is 7390; and the ratio of the number of species which are both recent and fossil is as 5.7 to 100.

The proportions of univalve and bivalve shells were found thus:

			Ratio to 100.
Living species....	Univalves......	3616	75.6
	Bivalves	1164	24.4
		4780	
Tertiary species ..	Univalves	2098	69.1
	Bivalves	938	30.9
		3036	

In these lists land and fresh-water shells are included to the number of 1465 recent, 259 fossil, of which

Fresh-water species .	Living bivalves .. 118	fossil .. 30
	Living univalves. 151	fossil ..151
Land species	Living 1196	fossil .. 78

Tertiary and living species compared.

The fossils are grouped by Deshayes under the following principal localities

1st Division.—Paris, London, Hants. Valognes, Belgium. The fossils of Castel Gomberto and Pauliac are considered the same, nearly, as those of Paris.

2d Division.—Bourdeaux and Dax, Touraine, Turin, Baden, Vienna, Angers, Ronca. The fossils of Moravia, Hungary, Cracovia, Volhynia, Podolia, and Transylvania are considered the same, with very few exceptions, as those of Vienna and Baden.

3d Division.—Italy, Sicily, the Crag. The fossils of Perpignan and the Morea are considered the same, with three or four exceptions, as those of Italy.

			Ratio of living species to 100.
Number of species from the Paris basin	1122 of which	38 are living	3.4
Bourdeaux and Dax.	594	136	22.9
Italy	569	238	41.8
Valognes	332		
Touraine	298	68	22.7
London	239	12	5.0
Sicily	226	216	95.1
Angers	166	25	15.0
Vienna	124	35	28.2
Crag	111	45	40.1
Baden	99	26	26.2
Turin	97	17	17.5
Belgium	49		
Ronca	40	3	7.5

Arranging these approximate results in the order of their ratios we shall have a descending series of analogies from the Sicilian deposits to the Paris basin.

Thus the analogy of fossil species to the living species is,

Sicily	95.0	Allied to existing species in the general ratio of	49 to 100
Italy	41.8		
Crag............	40.1		
Vienna	28.2	Ditto.	18 to 100
Baden	26.2		
Bourdeaux and Dax	22.9		
Touraine	22.7		
Turin	17.5		
Angers	15.0		
Ronca	7.5		
London	5.0	Ditto....................	3½ to 100
Paris	3.4		
Belgium, Valognes, Castel Gomberto, and Pauliac	none stated.		

In consequence of this comparison, M. Deshayes makes three groups of the tertiary series, according to the ratio of their analogy to existing kinds, as expressed

by the brackets above, and Mr. Lyell, from independent researches of a less extended character, was led to form the same scale of analogies, and, moreover, to separate the Sicilian fossils as still more recent than the others. He therefore divides the most recent group into two, and calls them newer and older pleiocene, (or pliocene,) the middle group he calls meiocene, (or miocene,) and the oldest group he calls eocene, as before explained.

Criticism on this scale of analogy would be at present wholly premature, and perhaps not respectful to the eminent Naturalist whose extraordinary knowledge and diligence have presented us with these most beautiful and impressive results. It appears to deserve remark, however, that the inland situations of the Vienna and Baden tertiaries may unfavourably influence the comparison for the fossils in these localities, from the causes before stated; and, perhaps, it may appear, if that circumstance could be properly compensated, that these localities should be removed from their association with Bourdeaux; and joined to the subapennine deposits, according to what seems to have been the inference of the observers on the spot.

Relation of tertiary shells to those in the . . . Paris;

The subject may be contemplated in another point of view; instead of inferring the relation of the fossil shells to one common upper term, *viz.* the shells of the actual seas, they may be compared to what has been assumed as the lowest term of the series, the basin of Paris. Because of the very great and admitted resemblance of the shells of Paris, London, Valognes, and Belgium, these may be grouped together, and we shall have the lowest tertiary epoch yet clearly made out represented by 1238 species, of which 42 are recent, and 46 are found in the deposits above them.

			Ratio to 100.
Shells of Bourdeaux and Dax	594, of which	27 are also Parisian,	4.6 nearly.
Touraine	298	8	2.6
Angers	166	7	4.2
Vienna	124	3	2.4
Baden	99	2	2.0
Turin	97	7	7.0
Ronca	40	10	25.0
Sicily, Italy, the Crag	777	4	0.6

From this Table we have the following scale for comparison with that previously given, the analogies to the Parisian formation increasing downwards.

Sicily, Italy, the Crag ....analogy	0.6
Baden	2.0
Vienna	2.4
Touraine	2.6
Angers	4.2
Bourdeaux and Dax	4.6
Turin	7.0
Ronca	25.0

The accordance of the two scales is very remarkable, and by both of them Ronca, as Deshayes conjectured, appears to demand a place in the Parisian group. Vienna, Baden, and Touraine here appear less related to the Parisian group.

to those of Touraine and Dax.

The relation of the Touraine fossils and the Bourdeaux and Dax fossils to the subapennine formations appears to be almost exactly the same; their relation to living types is also almost exactly the same. It is therefore evident that these beds may be joined together to make a new common term. We shall then have 743 species, and the analogy to this common term is for

Vienna	35.5
Baden	49.5
Turin	47.4
Angers	30.7
Subapennine	22.7
Parisian epoch	4.0

The analogy of the

Vienna and subapennine fossils is	40
Turin and subapennine	29
Bourdeaux and subapennine	22.5
Touraine and subapennine	23.4

General results.

The general result of these numerical comparisons would seem to give the following scale of antiquity amongst the several deposits.

		Lyell's Name.
Sicilian deposits.	Newer pleiocene.	Pleiocene.
Crag —— Subapennine deposits.	Older pleiocene.	
Vienna beds. Touraine——Bourdeaux and Dax——Baden——Turin. Angers.		Meiocene.
The Parisian and London deposits.		Eocene.

Having thus shown from M. Deshayes's data, the origin of the groups which he uses, and of the names of Mr. Lyell, we may present the following general results of the investigation of those authors, and refer to themselves for abundance of further information.

Eocene, or Parisian period. This should perhaps be considered as strictly applicable to the lower marine formation of the Paris basin, because it is almost wholly on the shells of that formation that the classification is founded.

Number of species of shells of this period	1238
Number of species also found in the meiocene period	66
Number of species also found in the meiocene and in the pleiocene period, and which may therefore be considered as characteristic of the whole tertiary system	17
Number of species identical with living kinds	42

Meiocene Period.

Number of species of shells	1155
Number of species common to the meiocene and the two other epochs	134
Real number of species of this period	1021
Number of species also found in the pleiocene period	196
Number of species identical with living kinds	176

Pleiocene Period.

Number of species of shells	777
Number of species identical with living kinds	350
Whole number of species of shells of the tertiary system	3036

Names of the seventeen shells which are characteristic of the tertiary system.

Four extinct or unknown in a recent state:
- Dentalium coarctatum.
- Tornatella inflata.
- Bulimus terebellatus.
- Corbula complanata.

Thirteen still living:
- Dentalium entale.
- strangulatum.
- Fissurella græca.
- Bulla lignaria.
- Rissoa cochlearia.
- Murex fistulosus.
- tubifer.
- Polymorphina gibba.
- Triloculina oblonga.
- Lucina divaricata.
- gibbosula.
- Isocardia cor.
- Nucula margaritacea.

Organic Remains of the Tertiary Strata.

The statement previously made that M. Deshayes has himself examined 3036 species of tertiary fossils, must be a sufficient reason for not following in respect of these strata the plan adopted for the less numerous

organic remains of the secondary and primary rocks. There is indeed not the same inducement or utility in such extended lists of tertiary fossils. They would not add any thing to the knowledge of periods given by the investigation which we have just ended, and the general resemblance in tertiary fossils of all ages and localities is too great to confer any particular interest on the enumeration of species. There is, probably, no more remarkable statement in any Science, than that of all the 3036 species of tertiary shells, *not one* should be found in any of the older strata. This statement could only be made and can only be verified by a skilful Conchologist; but the eye least practised in such observations can recognise the same proposition in another form. Many of the tertiary genera of fossil shells, and especially those which predominate in these strata, are either utterly unknown or very seldom seen in secondary strata, and thus whole tribes of shells are instantaneously pointed out, by one who is no Conchologist, as tertiary fossils.

The most useful lists of tertiary fossils will be such as are capable of direct comparison on leading points with catalogues formerly given for the secondary rocks. For this, the generic name and number of species must in general suffice. The marine deposits should be separated from those of fresh-water. The numbers of the species of shells are taken from Deshayes's Tables. The remainder from Brongniart, *Tableau des Terrains*.

Marine Deposits.

Plants, from M. Adolphe Brongniart.

	Species.		Species.
Agamia.		*Phanerogamia Monocotyledonea.*	
Confervites	2	Potamophyllites	1
Fucoides	11	Flabellaria	1
Cryptogamia.		Antholithes	2
Equisetum	1	Culmites	* 2
Tæniopteris	1	*Phanerogamia Dicotyledonea.*	
Phanerogamia Gymnospermia.		Exogenites	1
Pinus	2	Phyllites	7
Phanerogamia Monocotyledonea.		Juglans	1
Caulinites	1	Carpolithes	1
Zosterites	2		

Polyparia, chiefly from Brongniart and Goldfuss.

Caryophyllia	1	Eschara	1
Turbinolia	4	Ovulites	1
Astræa	2	Lunulites	3
Fungia	1	Alveolites	1
Madrepora	1	Favosites	1
Flustra	1	Isca	1
Orbitulites	1	Isis	2
Dactylopora	1	Glauconome	4
Polytripes elongata	1		

Radiaria.

Echinus	1	Nucleolites	1
Scutella	3	Galerites	2
Clypeaster	9	Spatangus	4
Cassidulus	2	Asterias	1

Articulated Animals.

Crustacea.

Atelecyclus	1	Palinurus	1
Leucosia	1	Sphæroma	1
Inachus	1		

Annulosa.

Serpula	4	Spirorbis	1

Cirripeda.

Balanus	5	Pyrgoma	1

Molluscous Animals.

Conchifera.

Plagymyona.

	Species.		Species
Aspergillum	1	Psammobia	4
Clavagella	9	Psammotea	1
Teredina	2	Tellina	54
Teredo	5	Corbis	2
Pholas	9	Lucina	59
Fistulana	7	Donax	15
Solen	19	Astarte	19
Pholadomya	1	Cyprina	7
Panopæa	3	Cytherea	59
Mya	5	Venus	43
Thracia	4	Venericardia	50
Hemicyclostera	2	Cardium	39
Lutraria	6	Cypricardia	7
Mactra	14	Isocardia	3
Mesodesma	7	Cucullæa	2
Erycina	23	Arca	54
Crassatella	24	Pectunculus	27
Amphidesma	1	Nucula	23
Corbula	35	Unio	2
Pandora	3	Anodonta	1
Saxicava	11	Chama	20
Petricola	10	Tridacna	2
Venerupis	6	Modiola	21
Sanguinolaria	2	Mytilus	15

Mesomyona.

Pinna	3	Gryphæa	3
Perna	4	Ostrea	72
Avicula	5	Hinnites	4
Lima	13	Vulsella	1
Pecten	60	Placuna	1
Plicatula	7	Anomia	8
Spondylus	9		

Brachiopoda.

Crania	3	Thecidia	
Terebratula	18		

Pteropoda.

Hyalæa	2	Cleodora	

Gasteropoda.

Chiton	1	Turritella	45
Dentalium	34	Proto	4
Patella	10	Cerithium	220
Umbella	1	Triforis	2
Parmophilus	2	Pleurotoma	156
Emarginula	11	Turbinellus	3
Fissurella	8	Cancellaria	42
Pileopsis	6	Fasciolaria	5
Hipponyx	12	Fusus	111
Crepidula	3	Pyrula	21
Calyptræa	15	Struthiolaria	1 ?
Bullæa	2	Ranella	8
Bulla	23	Murex	89
Pileolus	2	Triton	25
Neritina	17	Rostellaria	8
Nerita	16	Strombus	9
Natica	41	Cassidaria	8
Sigaretus	4	Cassis	15
Stomatella	1	Ricinula	1
Haliotis	1	Purpura	4
Tornatella	11	Monoceros	1
Pyramidella	8	Harpa	2
New genus	1	Dolium	1
Vermetus	1	Buccinum	95
Siliquaria	6	Terebra	16
Scalaria	22	Columbella	4
Delphinula	12	Mitra	66
Solarium	16	Voluta	32
Omalaxon	5	Marginella	17
Trochus	70	Volvaria	2
Pleurotomaria	1	Ovula	6
Monodonta	8	Cypræa	19
Turbo	34	Oliva	13
Littorina	10	Ancillaria	9
Planaxis	5	Terebellum	2
Phasianella	4	Conus	49

Cephalopoda.

	Species.		Species.
Beloptera	1	50 other genera including	232
Sepiostera	1		
Nautilus	4	No belemnites, ammonites, hamites, scaphites, turrilites, &c	
Nodosaria	21		

Fishes.

Of fishes it is estimated that 100 species belong to the marine tertiaries.

Of reptiles there are 6 crocodiles, 5 trionyx, 4 emys, 1 testudo.

Of cetacea; lamantin, delphinus 4 species, xiphius planirostris, balæna, Lin., 2 species.

Of other mammalia, phoca, trichlecus.

General Summary.

2975 species.

Plants	36 species.		
Polyparia	27		
Radiaria	23		
Crustacea	5		
Annulosa	5		
Cirripeda	6		
Conchifera plagymyona	736		
mesomyona	190	948	
brachiopoda	22		
Pteropoda	5	5	2747 mollusca.
Gasteropoda holostomata	469	1535	
solenostomata	1066		
Cephalopoda	259	259	
Pisces	100		
Reptilia	16		
Cetacea	8		
Other Mammalia	2		

Lacustrine Tertiaries.

Their age to be inferred from the remains of aquatic races.

As the marine shells afford the best or rather the only grounds for plausible deductions concerning the relative ages of the tertiary strata deposited from the sea, so the fresh-water shells and land shells must be employed to indicate the relative age of the many lacustrine deposits which diversify the tertiary districts, and cannot always, by any rule of superposition, be referred to either of the lacustrine deposits of Paris. In this research the plants also yield highly valuable evidence, but the land mammalia found with them ought surely to be excluded from the data which are to determine the age of the lacustrine sediments; because the changes of their races may, for ought we know at present, have been governed by wholly different conditions from those which affected the fresh-water or land shells and plants. Indeed, the case of shelly and osseous marl at Market Weighton, as well as every peat bog containing the Irish elk, proves that this suggestion is well founded. The era of the quadrupeds is to be determined from that of the lakes, not assumed to help out the deficient evidence concerning these latter.

A few cases, selected from the great number of tertiary lacustrine deposits, for the sake of some peculiar facts which they display, may now be introduced, to illustrate the condition of the surface of the land during the tertiary epoch. In general it is to be observed that, just as at the present day lakes sometimes occur on certain streams, in several parts of the valley, at different heights above the sea, and spread their waters over the Jura limestone, chalk, tertiaries, or primary strata, according to the nature of the country, so it was in the older time; and no criterion of the age of a fresh-water deposit is to be drawn from the marine nature of the strata on which it rests beyond the mere inference that it was posterior to such strata. If, as must frequently happen, the circumstances of these different lakes are unlike, the deposits in them may be related neither by similarity of order, nor identity of composition, but it is probable that some analogy will be traceable in their organic remains.

In the basin of Paris, gypsum occurs only in the lower fresh-water deposit, yet the gypsiferous fresh-water deposit of Auvergne, is supposed by Brongniart to be of the age of the upper fresh-water deposits.

Central France.

The fresh-water district of central France occupies considerable tracts along the lines of the Loire and the Allier, and is extended Northwards on the latter river, so as to approach towards the proper basin of Paris. The interesting phenomena presented by these deposits, where they have been subjected to volcanic agency about Clermont, the Cantal, and Puy in Velay, will be mentioned hereafter. Along the Allier, granite is the general basis of the fresh-water strata, which consist of sandstone and conglomerate, containing pebbles of all the primary rocks of the vicinity, but not of the volcanic rocks. Above these are green and white very finely foliated marls, full of the small bivalve crustaceous shells of cypris; thin tufaceous limestones, sometimes full of the larva—cases of phryganidæ; and the highest group of all in a few places is composed of gypseous marls. The most singular fact mentioned by Messrs. Lyell and Murchison, in their description of this country, is the remarkable condition of two of these groups. The lowest conglomerate series puts on almost exactly the appearance of the English old red sandstone, with its purple and green spotted marls, and even its nodular limestone or cornstone; and the limestone in the upper part of the series actually becomes oolitic at Vichy and Gannat, and yields a building stone like that of Bath, and of equal beauty; soft in the quarry, but gathering hardness by exposure. With what astonishment would the Geologist, acquainted with the fossils of the English oolite, gather in this oolite of Gannat, land shells and bones of quadrupeds, like those of the gypsum of Montmartre!

The lacustrine formation of the Cantal, rests in the same manner upon primary rocks, with sandy and gravelly beds below, gypsiferous marls, beds of flint and limestone above. This fresh-water limestone, and its accompanying flints, are described by Mr. Lyell as possessing a strong resemblance in mode of arrangement to the marine chalk and flint; the flint of the fresh water, black within, white without, and undergoing the same changes of superficial colour on exposure as the chalk flints of England.

Provence.

The same Geologists have been very successful in tracing the fresh-water deposits of Aix in Provence, which have yielded a large number of fossil insects, some fishes, and land plants of existing genera. M. De Serres also has described this locality, and studied the insects with attention. The general basis of the Aix tertiaries, is a rock of the oolitic system, inclined and contorted in position, with gryphæa, belemnites, and ammonites. The lacustrine deposits are in the lower part a series of carboniferous limestones and shale, with stony bituminous coal in several seams which altogether amount to five feet in thickness. The limestone is compact, grey, blue, and black, and resembles the mountain limestone of England. Fresh-water shells (cyclades, melania, planorbis unio) accompany these beds, and gyrogonites are found in the coal itself. Micaceous sandstones and shales, with earthy limestone and limneæ, come on above; and these are succeeded by red marl and fibrous gypsum, also characterised by the pre-

sence of limneæ and planorbes. Under and above the town of Aix, the upper series of the basin is observed to consist of red sandstone and conglomerate, covered by white and pink-coloured marlstone and marl; and above all is a triple succession of gypsum and marls, overlaid by white calcareous marls and marlstone, with calcareo-silicious millstone and resinous flint, containing land and lake shells. It is in these beds that the fossil fish occur abundantly, and leaves and branches of flabellaria, laurus, buxus, &c. are found. The insects are obtained from a parting in the upper gypseous beds. They are, with one exception, all land insects; and from the united testimony of M. De Serres and Mr. Curtis, referable or nearly related to existing genera, principally of the orders diptera and hemiptera, some coleoptera and hymenoptera, but only one lepidopterous insect: sixty-two genera are particularly enumerated by M. De Serres. May we not compare this curious and as yet almost unique fact in tertiary Geology to the collection of insects, leaves, and branches, which, when swept down by Spring or Summer floods, affords a rich harvest to the Entomologist on the borders of the rivers in the North of England?

Œningen.

The limestone quarries of Œningen, near Schaffhausen, have long been celebrated for abundance of mammalia, birds, reptiles, fishes, insects, and plants, identical or very similar to existing kinds. The section of the whole deposit is given by Mr. Murchison, who brought from this locality, in 1828, one of the most remarkable fossils which has ever been found—the entire and connected skeleton of a fox. The upper quarries offer a section of thirty feet, the beds changing downwards from brown clay into cream-coloured indurated marl, and afterward into a fissile fetid marlstone, containing flattened shells of planorbis, small limneæ, and cyprides; to these succeeds light-coloured, fetid, calcareous building stone, beneath which is a finely laminated bed, containing insects, cypris, shells of anodon, and many plants; then follow two thin beds of fetid limestone, in the upper of which a large tortoise was found, and in the lower one the fox. Below are slaty marls and marlstones, limestone, and building stone, with a repetition of finely laminated layers of marl, with plants and fishes; the general base is the molasse of Swisserland. Excepting this fox, which is very much allied to the common fox of Europe, all the other quadrupeds found here are rodentia. The insects and plants belong to European genera.

These descriptions of some of the most interesting lacustrine deposits, will render it unnecessary to particularize other numerous cases in Swisserland, Germany, Hungary, Italy, and Spain, which present nearly the same phenomena, and appear to occupy the whole interval of time from the lower fresh-water formation of Paris to the diluvial era, and to be represented by an equally continuous series of detached desiccated lakes from that era to the present time.

Lignite

There is, however, another kind of fresh-water deposit which requires a short notice. Lignite, or wood coal, has long been known in France, in connection with the plastic clay group and other more recent strata, and also in the Isle of Wight. The same kind of carbonaceous deposit is of value in the molasse of Swisserland, and very extensively spread over the North of Germany, and in the Valley of the Rhine; it also interlaminates extensively the marine tertiaries of the basin of Vienna and the border of the Carpathians: lignitic coal has therefore been considered as even peculiar to the tertiary era. This is not quite correct, yet the generalization is of more importance than perhaps we may at present perceive.

The whole mass of these lignites is made up of land plants, mostly or wholly of dicotyledonous tribes, and they are accompanied by marls, land and fresh-water shells, and, in places, by the bones of paleotheria, anthracotheria, beaver, &c. The fixing of their relative age is hardly possible by evidence drawn from themselves alone, for the shells and plants are few, and the quadrupedal remains very local. If we attempt to fix their date by that of the marine strata which they divide, the uncertainty of the latter datum must, in a great measure at present, frustrate the attempt. Perhaps the most recent deposit of this kind mentioned on the Continent, is that described by De Beaumont as associated with the older diluvium, as it has been considered, which that author ascribes to the uplifting of the Western Alps. This deposit bears marks of slow and tranquil accumulation in a lake, contains planorbes in the layers of clay which alternate with it, and sometimes shows as many as four beds; it rests on and is covered by pebbles, which indicate violent watery action.

It is highly probable that lignite has been formed at many periods, and that deposits of this kind will be found at intervals from the plastic clay, through the diluvial gravel and clays to the modern alluvial peat bogs, which they so much resemble in alternation and repetition of materials, paucity of shells, occasional occurrence of quadrupedal remains, and almost every obvious circumstance.

Lignite of Bovey Tracey.

Bovey Tracey, in Devonshire, is the only locality in England where tertiary lignites are worth working; the exact Geological age of this deposit is not known at present. Pipe-clay of some value lies with it. Dr. Miller, in the *Phil. Trans.* vol. li. describes this deposit in a very interesting manner. The whole series dips to the South about twenty inches in a fathom. The perpendicular thickness of these strata, including the beds of clay with which they are intermixed, is about seventy feet. There are about six of each, and they are found to continue Eastward, in an uninterrupted course, to the village of Little Bovey, a mile distant, and probably much further. The strata of coal, near the surface, are from eighteen inches to four feet thick, and are separated by beds of brownish clay, nearly of the same dimensions, but diminishing in thickness downwards, in proportion as the strata of coal grow larger; and both are observed to be of a more compact and solid substance in the lower beds. The lowermost stratum of coal is sixteen feet thick; it lies on a bed of clay, under which is a sharp green sand of seventeen feet thick, and under that a bed of hard coarse clay, into which they have bored but found no coal. From the sand arises a spring of clear blue water, which the miners call mundic water, and a water of the same kind, trickling through the crevices of the coal, tinges the outside of it with a blue cast. (Phosphate of iron.)

Amongst the clay, but adhering to the coal, are found lumps of a bright yellow loam, which burn with an agreeable scent. (Retinasphalt.) Some of the coal is black, and nearly as heavy as pit coal; this is called stone coal; but the most remarkable sort resembles wood in the grain and appearance so much as to be called wood or board coal. Some plants like grass and reeds lie in the alternating clays, which are in part carbonaceous.

The following section of the Meissner by M. Herndeshagen (*Leonhard Taschenbuch*, 1817) gives the most usual relations of the brown coal and basalt of that celebrated locality.

1. Dammerde.
2. Greenstone and basalt, 50 to 80 fathoms ..... 300 to 480 feet.
3. Schwül, (blind coal,) a bituminous laminated clay, hardly to be distinguished from true coal .... ½ to 5 feet.
4. Kohlenflöz, in all 3 to 14 fathoms thick, viz. — 3 to 14 fath.
   - *a.* Stangenkohle (prismatized).. 1 to 4 ft...
   - *b.* Glanzkohle (sp. gr. 1.438) .. 3 to 18 ft ..
   - *c.* Pechkohle (sp. gr. 1.346) ... 3 in. to 3½ft.
   - *d.* Brownish black (sp. gr. 1.259) 3 to 4 ft. ...
   - *e.* Light brown light coal (sp. gr. 1.230) .... 4 to 8 fath..
   - *f.* Fossil wood, called stockwerk 6 in. to 4 ft.
5. Liegende, (sill or sole of the coal,) sp. gr. 2.545
6. Triebsand .... ½ fathom.
7. Blue marl, on the East of the mountain, with gypsum........................... 10 to 15 fath.
8. More or less friable sandstone 1 fathom, then sandstone to the foot of the mountain on the East side, but on the West side muschelkalk.

Organic Remains of Lacustrine Tertiaries.

Plants from M. Adolphe Brogniart.

Agamia.

Cryptogamia cellulosa.

Muscites Tournalii	Armissan near Narbonne.
squamatus	Longjumeau near Paris.

Crypt. vasculosa.

Equiset. brachyodon	Armissan.
Filicites polybotrya	Ditto.
Lycopodites squamosus	Paris.
Chara Lemani	St. Ouen near Paris.
tuberculosa	Isle of Wight.
medicaginula	Montmorency, Sanois, Trappes near Paris.
helicteres	Pleurs, Department de l'Aisne.

Phanerog. gymnosperma.

Pinus pseudostrobus	Armissan.
Taxites Tournalii	Ditto.

Phanerog. monocotyledonea.

Smilacites hastata	Ditto.
Flabellaria Lamanonis	Aix en Provence.
Endogenites	Montmartre.
Poacites	Aix.

Phanerog. dicotyledonea.

Comptonia dryandræfolia	Armissan
Betula dryadum	Ditto.
Carpinus macroptera	Ditto.
Phyllites lævigata	Aix, Armissan, Pavia, &c.
Geslini	Aix.
Nymphæa arethusa	Longjumeau.
? Culmites anomalus	Ditto.
Carpolithes thalictroides	Ditto, Isle of Wight.
ovulum	Longjumeau.
Exogenites	Palaiseau.

Conchifera.

Unio Solandri, Sow.	Isle of Wight, Hordwell.
Cyclas	Aix en Provence.
Anodonta Lavateri	Œningen.
Mya ? gregaria, Sow.	Headon Hill.
Corbula nitida, Sow.	Isle of Wight.
Cyrena pulchra ?	Hampstead Bay; Skye.
Mytilus Brardii, Sow.	Hordwell.

Mollusca.

Gasteropoda.

Planorbis rotundatus, Sow.	Paris, Salinelle, (Gard,) Quercey.
cornu	Paris.
euomphalus, Sow.	Isle of Wight.
prevostinus	Ditto, Paris.
Planorbis prominens	Salinelle.
compressus	Ditto.
lens	Isle of Wight, Paris.
cylindricus, Sow.	Isle of Wight.
Limnea fusiformis, Sow.	Headon Hill.
minima, Sow.	Ditto.
maxima, Sow.	Binstead.
longiscata, Lam.	Headon.
pyramidalis, Sow	Ditto.
columellaris, Sow.	Hordwell.
cornea	Paris, Colle en Siennois.
fabulum	Paris.
ventricosa	Ditto, Bruere. (Cher.)
inflata	Bruere.
cylindrus	Ditto.
strigosa	Le Locle near Neufchatel.
elongata	Paris.
acuminata	Ditto.
æqualis	Salinelle.
pygmæa	Ditto.
ovum	Paris.
Paludina affinis	Salinelle.
impura	Quercy.
Hammeri	Isle of Wight, Bouxweiler.
carinata	Paris.
Ancylus elegans	Hordwell.
deperditus	Salinelle.
Melania fasciata	Isle of Wight.
Melanopsis carinata	Newport, Isle of Wight.
brevis	Hordwell, &c.
Phasianella orbicularis	Shalcomb, Isle of Wight.
angulosa	Ditto.
minuta	Ditto.
Potamidum Lamarckii	Paris, Aurillac, Nonette, near Issoere.
acutum	Isle of Wight.
ventricosum	Ditto.
Indusia tubulata ?	Moulins, Auvergne, Colle.
Cyclostoma truncatum	Paris, Carnetin.
elegans antiquum	Paris.
mumia	Ditto.
Helix globosa	Shalcombe, Isle of Wight.
Lemani	Paris.
Desmarestina	Ditto.
*Ramondii	Orleans, Auvergne.
Cocqui	Ditto, ditto.
Bulimus pygmæus	Paris.
terebra	Ditto.
atomus	Paris, Le Puy.
pusillus	Ditto.
Pupa Defrancii	Paris and Auvergne, in a piperine.
muscorum	

Arachnida, Insecta, &c.

Aranea	Aix en Provence.
Phrynus.	
Coleopt. Dytiscus.	
Staphylinus.	
Buprestis.	
Melolontha.	
Curculionidæ	10
Trogosita.	
Hylophagidæ	5
Orthoptera	8
Hemiptera	20
Neuroptera Libellulidæ.	
Hymenoptera	8
Lepidoptera	2
Diptera	15

Fishes.

Mugil cephalus	Aix in Provence.
Perca minuta	Ditto and Paris.
Cyprinus squamosus	Ditto, ditto.
bipunctatus	Œningen.
jises	Ditto.
capito	Ditto.
minutus	Paris.
ictus	Rochesaure. (Ardeche.)
tinca	Cadix.

Pæcilia Lametherii	Paris.
Anormurus macrolepidotus	Ditto.
Esox	Œningen.
Amia ignota	Ditto.

Reptiles.

Crocodilus gypsorum, Cuv.	Paris, analogous to alligator.
Argentoni, Cuv.	Argenton, ditto.
Salamandra gigantea	Œningen.
Triton palustris	Ditto.
Rana	Ditto.
Trionyx gypsorum, Cuv.	Paris.
Maunoir	Aix and Paris.
des molasses	La Grave, L'Agenois, Le Quercy, Haute Vigne, (in Lot and Garonne,) Castelnaud.
Emys gypsorum, Cuv.	Paris.
Testudo of Aix	Aix.

Birds.

Several species	Paris, Auvergne, Œningen.

Mammalia.

Palæotherium magnum	Paris, La Grave, Dordogne, (also Binstead, Isle of Wight.)
medium	Ditto.
crassum	Ditto.
latum	Ditto.
minus	La Grave, Paris.
minimum	Paris.
aurelianense	Orleans.
Isselanum	Issel near St. Papoul.
Anoplotherium commune	Paris, (also Binstead, Isle of Wight.)
secundarium	Paris.
Xiphodon gracile	Ditto.
Dichobunes leporinus	Ditto.
murinus	Ditto.
obliquus	Ditto.
Chæropotamus Parisiensis	Ditto.
Anthracother velaunum	Puy en Velay.
Lophiodon major	Argenton, Issel, Soisson, Gannat, Montabuzard.
secundarius	Argenton.
minor	Paris.
pygmeus	Ditto.
maximus	Bastberg, near Bouxweiler.
secundus	Bastberg.
Monspeliensis	Boutonnet, Montpelier.
quintus	Argenton.
Canis Parisiensis	Paris.
Vulpes	Œningen.
Genette des Platrieres	Paris.
Coati des Plat	Ditto.
Didelph. Parisiensis	Ditto.
Ecureuil des Plat	Ditto.
Loir des Plat	Ditto.
—— second	Ditto.

Lignitic Tertiaries.

Plants. (No marine.)

Coniferæ.	
Pinus sphærocarpa	Erxleben near Helmstædt.
ornata	Walch in Bohemia.
familiaris	Triblitz in Bohemia.
Taxites acicularis	The Meissner.
tenuifolia	Comothau in Bohemia.
diversifolia	Cassel.
Langsdorfii	Nidda near Frankfort.
Juniperites brevifolia	Comothau.
acutifolia	Ditto.
? aliena	Schmetzna in Bohemia.
Thuya gracilis	Comothau.
Langsdorfii	Nidda.
graminea	Perutz. (Bohemia.)
Naiadæ.	
Potamophyllites multinervis	Mont Rouge near Paris.
Palmæ.	
Palmacites echinatus	Wailly near Soissons.
Flabellaria raphifolia	Haring in Tyrol, Lausanne, Vinacourt near Amiens.
Phœnicites pumila	La Chartreuse de Brive. (Velay.)
Cocos (Parkinsonis)	(Sheppey.)
Faujasii	Liblar near Cologne.
Burtini	Woleuve near Brussels.
Monocotyled. incerta.	
Endogenites	Liblar, Horgen near Zurich.
(Amomocarpum depressum)	(Sheppey.)
(Pandanocarpum pyramidat.)	(Ditto.)
Dicotyledoneæ.	
Amentaceæ.	
Comptonia acutifolia	Comothau. (Bohemia.)
Salix ?	Nidda.
Populus ?	Ditto.
Castanea ?	Menat.
Ulmus	Comothau.
Juglandeæ.	
Juglans ventricosa	Nidda.
lævigata	Ditto.
Acerineæ.	
Acer Langsdorfii	Ditto.
Dicotyl. incerta.	
Exogenites	Universal.
Phyllites cinnamomifolia	Meissner.
Carpolithes (many)	Nidda.
Leaves, &c. (many)	Ditto.

Conchifera.

Unio ovatus, St.	Swisserland.
Cyclas palustris	Ditto.
Cyrena antiqua	St. Marguerite. (Dieppe.)
tellinoides	Soissons.
cuneiformis	Ditto.
Crawfordi	Irawadi.
Ostrea Bellovacina.	
incerta.	

Mollusca.

Nerita globulus	Epernay.
pisiformis	Ditto.
sobrina	Ditto, Soissonnois, &c.
Ampullaria Faujasii	St. Paulet. (Gard.)
Melanopsis buccinoides	Epernay, Soissons, Cuiseau, Headon Hill, Italy, Sistos, &c.
costata	Soissons.
Melania triticea	Epernay.
Escheri	Kœpfnach near Zurich.
Paludina virgula	Epernay.
unicolor	Soissons.
Desmarestii	Paris.
Limnea longiscata	Ditto.
Physa antiqua	Epernay.
Planorbis rotundatus	Soissonnois, Bagneux, Paris, &c.
regularis	Cezenon. (Herault.)
incertus	Bagneux, Epernay.
punctatus	Ditto, ditto.
Prevostinus	Paris.
Cerithium melanioideum funatum	Epernay, Anvert, Bagneux, Paris, &c.
Ampullaria depressa	Epernay, Anvert, Bagneux, Paris, &c.

Reptilia.

Crocodilus d'Auteuil	Near Paris.
vulgaris	Irawadi.
de Provence	Mine de Memet (Provence.
Leptorhyncus	Irawadi.
de l'Inde	Ditto.
Trionyx de l'Inde	Ditto.
Salamandra ogygia, Goldf.	
Triton Noachicus, Goldf.	
Rana diluviana, Gold.	
Ophis dubius, Goldf.	

Mammalia

Mastodon angustidens	Kœpfnach near Zurich.
elephantoides	Irawadi.

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Mastodon latidens	Irawadi.
Hippopotamus	Ditto.
Rhinoceros	Kœpfnach, Irawadi.
Tapir....................	Irawadi.
Anthracotherium magnum	Cadibona. (Tuscany.)
minus	Ditto.
minimum............	Ditto.
alsaticum............	Lobsan.
silistrense............	Caribari. (Bengal.)
Lophiodon Laonnense	Department de l'Aisne.
Bos	Irawadi.
Castor des lignites	Kœpfnach.

Dislocations of the Tertiary Strata.

After the deposit of the chalk and the plastic clay strata, and after the accumulation upon it of several regular marine tertiary strata, extensive disturbances happened, by which the chalk and all the older strata were thrown into new positions, and the whole configuration of the land in the Northern zones was greatly changed.

South of England. In England, the effects of general convulsions at this epoch are very striking in the Southern Counties, and chiefly referable to two nearly parallel great undulations of the strata, of a peculiar character, ranging East and West. These undulations are of such a kind, that there are two axes of elevation and two parallel troughs. The Northern trough is nearly in the line of the Thames from London to Reading, beyond which it appears to end; the Southern trough is directed along the Solent, towards the extension of the chalk beyond Dorchester, beyond which it also appears to end. The Northern axis of elevation passes through the Weald of Kent and Sussex, South of Guilford to Highclere in Hampshire, and is continued along the Vale of Pewsey, but ends toward Devizes. The Southern ridge of strata passes through the Isles of Wight and Purbeck, and between Weymouth and Bridport, and ends at some point in the Channel before arriving at Torbay.

These great undulations appear evidently caused by violent elevation of the strata along the two lines described; and it is exceedingly remarkable that the effect of the convulsion is such, that in each case the declination of the strata on the North side is generally very steep or *even vertical*, as at Guilford on the one ridge, and in the Isles of Wight and Purbeck on the other, while on the South side the chalk in Hampshire, and the green sand and oolitic groups in the Isles of Wight and Purbeck, are nearly level or slope gently to the South.

It is further observable, that for a certain length in the middle of each axis of elevation the strata are vertical or nearly so, on the North side, but on each side of this length the inclination becomes less and less violent, and at considerable distances, in one of the ridges, is reduced to a gentle slope. Thus, on the Northern ridge, the strata are violently inclined along the line by Highclere in Hampshire, (*where the chalk attains its greatest elevation in England,*) and at Guilford, but both Westward toward Devizes, and Eastward toward Kent, the slopes become gentle. Also on the Southern ridge, the strata are *highly* inclined North of Weymouth, *nearly* vertical in the Isle of Purbeck, but *absolutely* vertical at the Western end of the Isle of Wight, and in Culver cliffs (Eastern end of the Isle of Wight) instead of being vertical are inclined 70° North.

From these data we may infer confidently that the disturbing force acted from below along particular lines, and most violently at certain points in these lines; and because of the unequal declinations of the strata on the opposite sides of the ridges, we may perhaps admit the force to have been exerted in *an oblique direction.* This latter conclusion has often been suggested to us while considering the ordinary phenomena of *faults.*

Diluvial Deposits.

We have now concluded the history of the deposits formed on the beds of the ancient sea, in its depths, along its shores and in its estuaries, and we have noticed the contemporaneous or alternating accumulations from the fresh waters which then flowed upon the Earth. The tertiary system of strata, by showing us remarkable alternations of fresh-water and marine deposits, appears to establish a connection between the ancient and the modern World, between the subaqueous and the elevated land.

The whole of that system presents us with strong analogies to the present order of things, in its races of animals and plants; and its fresh-water deposits have often a clear relation to the present level of the continents, and on this account might be viewed as the oldest of the alluvial formations.

Yet upon closer inquiry it will be found that in many cases a very strong line of distinction is drawn between the tertiary formations and the true alluvial accumulations, by the intervention of an irregular mass of deposits, evidently produced by inundations of extraordinary violence upon the face of the dried and inhabited Earth. These deposits are so extensive, and over large tracts of the Earth's surface have so much of a common character, that they have very generally been classed as the productions of one turbulent period in the process of the formation of the Globe, and termed the Diluvial deposits.

This term was first employed by Mr. Smith, and when subsequently adopted by the English School of Geology, it was often understood to refer to the effects of the Noachian Deluge; and though on this point opinions are now more unsettled and various, the term may still be very properly employed by Geologists of every School to mark the effects of turbulent inundations upon the inhabited land, happening within a particular period in the History of the Globe. In this sense we employ it. Origin and use of the term.

Without entering upon the unprofitable history of the delusions in which Geologists have involved themselves on the subject of the Noachian Deluge, it will be proper to remark that all discussions of this nature are useful or injurious according as they are carried on independently of or in connection with Theology. Burnet and Woodward, by mixing up false hypotheses with Scriptural History, retarded the progress of Geological Science, and sanctioned a perverse application of the Mosaic narrative to support every new, fanciful, and unsubstantial theory.

We must always bear in mind that it does not follow that all deluges must be referred to the Noachian flood; certainly many turbulent waves have traversed the Globe before the creation of man; some local deluges have happened since the days of Noah. It may therefore very possibly be true that the turbulent waters of which we are now to trace the effects upon the surface of the Earth, may be quite independent of the Deluge of Scripture; we have no right to *assume* any connection between them; and at all events it will be prudent before thus entangling ourselves in fetters which it may be difficult to unclasp, to wait for a full investigation of the subject. Many curious questions of time and circumstance are involved in such a comparison which it will be wise to reconsider.

There is nothing in Geology less improbable than the

occurrence of a period of violent watery action, for in the course of our survey of the stratified rocks, we perceived clearly that, during their production, long periods of regular and ordinary action have been frequently succeeded by temporary disturbance. The epochs of these disturbances relatively to other phenomena are precisely assignable. They differ in importance, and while some are so great and extensive as to afford means of classifying the strata over large surfaces of the Globe, others seem to have happened locally and irregularly.

The present system of Nature may be considered as one of the periods of regular action, and the effects now produced upon the land and in the sea are of the same kind as those occasioned during the comparatively tranquil periods of older nature, because upon the whole the levels of sea and land are constant. But the deposits called diluvial are characteristic of a period of watery tumult and disturbance of the most extensive kind, and are to be associated mentally with other great epochs of disturbance which mark temporary convulsions in the ancient system of Nature. This watery tumult differs, however, from all anterior deluges, by the circumstance that we are looking upon the land and reading there the traces left by violent waves, while those of ancient times are known to us only by the effects they produced in the sea.

Proofs.

We shall now present the proofs of such a system of turbulent waters having passed over large portions of the surface of the inhabited Earth, since the formation of all or nearly all of the stratified rocks now visible above the Ocean, and since the present continents were dried, elevated, and inhabited.

Detritus from the Cumbrian mountains.

1. Without venturing to assert that every region of the Earth's surface is covered by the water-moved ruins of rocks, and waste of distant mountains, in situations to which existing streams could not carry them, we may state that observations of this nature are general for all parts of the Continent of Europe, Northern Asia, and Northern America, Countries which have been, better than any other, explored by Geologists. In all these regions, great deposits of gravel, sand, and clay, containing in more or less abundance portions of all the known rocks and strata, lie spread over formations of every age, primary, secondary, and tertiary. There is no order in the arrangement of these heterogeneous materials, no constant series or succession of deposits, but the utmost confusion and irregularity. The materials lie sometimes in valleys, often on hills, crossing in their course both hills and valleys, and appearing to have little relation to the track of the existing streams, though sometimes evidently influenced by the great physical features of the districts. Though the subject of the direction of diluvial currents, with reference to local geography, has not been sufficiently attended to, even in England, we are able to bring forward some striking instances in support of the preceding statements. It is well known that the mountain group of Cumbria encloses remarkable kinds of granite, sienite, and other rocks, and that they are separated from the Eastern parts of the Island by a long unbroken range of carboniferous limestone stretching from the Tyne to the Aire. A considerable hollow every where divides these ranges; and in some parts, as in the vale of Eden, the hollow is from 1000 to 2000 feet, or more, below the summits on either hand. The lowest point in the whole line of carboniferous limestone, which offers itself directly to the West, is on Stainmoor, about 1500 feet above the sea. Now by the force of the currents of water alluded to, blocks of the curious porphyritic granite of Shap Fells have been removed from their original sites, (1500 feet above the sea,) swept over a ridge of limestone rocks about Orton, into the red sandstone vale of Eden, and from this deep and ancient vale lifted up the steeps of Stainmoor to the very summits of the pass. From thence they have been urged forward as from a new centre, and spread in a radiating manner over the South of Durham, and the whole extent of the vales of York and Cleveland, to the foot of the Hambleton Hills and the Wolds. Against these great barriers, considerable quantities of the rocks of Cumberland, and likewise of the carboniferous system of Yorkshire, are collected, but a large portion of the débris has also travelled over and beyond parts of these high districts and reached the sea side, where many of the cliffs are covered by blocks swept from Cumberland and North-Western Yorkshire. In passing from Shap Fells to Holderness, the granitic boulders have been transported across two deep vales, and over two elevated ranges of hills. In passing over these hills, we clearly perceive that the blocks were wafted by the easiest ascents. This is remarkably the case at Stainmoor, the lowest point in the long carboniferous summit, and the only one crossed by the diluvial boulders. It is therefore evident that at the period when these violent waters flowed over the North of England, the land had assumed its present general shape and altitude; it is also clear that the floods were influenced in their direction by the great physical features of the country, but that at particular points they were of force and volume enough to overcome these natural obstacles.

Besides the porphyritic granite of Shap other remarkable rocks of the Eastern part of the Cumbrian mountains have followed the same course. The hypersthenic and sienitic rocks of Carrock Fell, the brecciated and amygdaloidal slates of Grasmere, Ulswater, &c. may be often recognised in the same situations. Perhaps the most instructive of all examples derived from this country is that furnished by the red "brockram" of Kirby Stephen. This member of the saliferous formation is easily known by its fragments of carboniferous limestone imbedded in red sandstone, and its native site is in the depth of the vale of the Eden. From this deep repository it has been lifted by the diluvial currents over Stainmoor, and thence carried with the granites and other rocks of the Cumbrian group.

The currents to which these effects are ascribed, must have flowed from the North-West. From the Western part of the Cumbrian group of mountains, currents flowing nearly from North to South have carried the granite of Ravenglass and Muncaster along the low ground West of the carboniferous chain of Yorkshire and Lancashire to the vicinity of Manchester, and through a great part of Staffordshire; but this sort of granite has no where crossed the carboniferous chain, to spread down the valleys of the Aire, Dun, Derwent, or Dove. In this case, as in the former, it is evident that the current was directed by the great physical features of the country, which were the same then as now.

From the Lickey Hill.

The quartz pebbles of the Lickey have been widely diffused over the plains of Warwickshire and Gloucestershire to the foot of the Cotswold Hills, but on arriving at this barrier they are stopped, except at two low points, the summits of the valleys of the Cherwell and the Evenload. Down these valleys, and along their borders, the pebbles hold separate courses till the streams unite near Oxford, after which the general course of the

valley of the Thames is the line of the diluvial deposits.

A tendency to be arranged in narrow, longitudinal spaces is sometimes observable in the diluvial accumulations. In Lincolnshire a long narrow ridge of diluvial chalk runs out in a South-Westward direction by Faldingworth. In Yorkshire the lias boulders from Robinhood's Bay keep nearly parallel to the present North and South line of coast; and the flinty gravel from the Wolds runs North and South from Pocklington to Cave. These observations will probably be much extended hereafter.

From the Alps.

The most extraordinary effects of tumultuous waters upon the surface of the land, appear sometimes to surround lofty ranges and groups of mountains. Thus the Mont Blanc group of primary mountains has been rent to pieces by some violent convulsion, and its mingled fragments transported along the *lines* rather than in the actual channels of the Rhone and the Arve into the Valais, along the Lake of Geneva, and up the slopes and through the valleys of the Jura even far into France. By this extraordinary course, blocks of enormous magnitude have been drifted in great numbers on to the tops of mountains, even to the height of 2000 or 3000 feet above the Lake of Geneva, and left there in such abundance as to encumber the land with thousands of extraneous masses. There appears in these collections of blocks a very singular tendency to association in groups and lines. (De Luc.) It is particularly to be remarked that no ordinary action whatever could possibly cover the abrupt mountains of the Saleve and Mont Sion with such immense and numerous masses of these rocks, or transport them across the deep and wide valley of the Rhone to the steep slopes of the Jura. For such powerful effects it will be difficult to assign an adequate cause, and however much influence we may ascribe to the impetuosity even of an uplifted sea possibly cooperating with the disruption of glacier-covered mountains, the phenomenon must ever appear of the most remarkable kind.

We seem to perceive, on a general view of the dispersion of these *erratic blocks* from the Alps, a remarkable relation to the existing valleys. While the Mont Blanc group have yielded fragments to the Rhone and the Arve, the Bernese oberland has supplied the basin of the Aar and the neighbouring part of the Jura; the valley of the Reuss has conveyed the waste of the mountains at its source; blocks from Glaris lie by the Lake of Zurich, and the valley of the Rhine holds the rocks of the Grisons.

The great range of the Jura, opposed to the Alps, and separated from them by the long and wide valley of the Aar prolonged into the Lake of Geneva, has furnished the best opportunity of determining the geographical and other data belonging to the curious problem of the dispersion of these blocks. It is certain that in their course from the Alps the blocks have principally followed the line of the present valleys, since they are found along their sides in greatest plenty, and are collected in most abundance, and lie at the greatest heights, on those parts of the Jura chain which directly face the embouchures of the valleys. Yet this relation to the valleys is of such a kind, that the blocks, instead of being limited to their beds, lie perhaps more plentifully on the hill sides, and intimate a totally different kind of watery action from that of the running streams. Some general convulsions under water, at once elevating the mountains and opening the valleys, and pouring along the floods, may safely be concluded to have caused the phenomena

One of the grandest examples of the form and continuity of diluvial currents is the dispersion to the Southward, across the Baltic, of the primary and transition rocks of Sweden and Norway. Brongniart (*Tableau des Terrains*) has given an excellent view of these phenomena.

From Scandinavia.

The sandy plains of Westphalia, Hanover, Holstein, Zeeland, Mecklenburg, Brandenburg, the coasts and plains of Pomerania, Prussia, and part of Poland far inland between Warsaw and Grodno, and consequently all the low, generally flat, and sandy Countries which border the Baltic and the German Ocean from the Ems and the Weser to the Dwina, and even the Neva, are covered at intervals by these blocks. They are not uniformly dispersed, but collected in particular spaces, and form in the midst of these vast sandy wastes distinct groups, generally elliptical in outline, with the longer axis directed North and South, or toward the Baltic Sea. Bruckner mentions a *trainée* of these blocks in the Northern part of Mecklenburg-Strelitz, which runs from West North-West to East South-East. They are more abundant on hills than in valleys. The largest blocks are most superficial and nearest the tops of the hills. They consist of granites, sienites, transition limestone with trilobites, &c., and other rocks which have the greatest resemblance to the rocks of Sweden; they contain the same *peculiar* minerals, and the same *peculiar* organic remains. Their course from the Scandinavian peninsula is generally from North-East to South-West. On approaching the mountains whence they were dislodged, we find the *number* of the blocks to increase considerably, and on crossing the Sound to Scania, they appear at every step, but the *size* of the blocks is not greater. The mountains of Sweden are not more burdened by loose blocks than is common to such tracts, but the faces of the rocks there appear furrowed and rubbed by the drifting of heavy bodies. The Baltic Sea, which crosses the line of these *trainées of rocks*, appears to have interposed no obstacle to their movement, since the heaps of blocks lie in the same direction on both sides of the water, and the quantities carried over are immense.

Many of the granitic boulders on the coasts of Yorkshire and Norfolk are thought to have come from the same Scandinavian mountains. From observations in England, Dr. Buckland inferred that the general direction of the diluvial currents was from the North-West. In North America, Dr. Bigsby and other observers have observed the prevalent direction to be from the North-West or North-East; the Scandinavian blocks have travelled also from North-East or North North-East. But the waste of the Alps has gone nearly as the valleys run, in all directions; Southward to Italy, Westward to France, Northward to the Rhine, and generally we may be assured that the prevalent direction in any Country has a very close relation to the physical geography of the region.

The degree of attrition of the erratic blocks is various, and generally not so considerable as that of the smaller pebbles which compose the greater part of the diluvial masses.

Inference.

From the preceding data we are warranted in concluding that since the deposition of all or nearly all the marine strata which are seen in our continents, and since the actual land was uplifted from the sea, and shaped into its present leading physical features, large parts of the Earth's surface have been deluged by floods

passing in various directions, which removed large quantities of the preconsolidated rocks, and dispersed them over distant Countries, in such abundance, of such magnitude, to such distances, in such directions, and to such altitudes, as to preclude the possibility of explaining the phenomenon by the action of *actual streams*, flowing in the ordinary course of nature, or deviating in any possible manner over the surface of the Earth, or by the bursting of lakes, however situated or circumstanced. For neither streams nor bursting lakes could possibly transport the Shap Fell granite to Flamborough Head, nor drive the sienites of Sweden into the heart of Poland.

Gravel deposits.

For the sake of exhibiting decided proofs of the powerful action of the diluvial waters, we have insisted much on the transport of large blocks of recognisable rocks; but it must not be imagined that such blocks of such magnitude compose the whole or the greater part of the diluvial deposits. These consist, in fact, of the detritus and fragments of every sort of rock, and of all sizes, from the giant blocks on the Jura to the finest sand and sediment. The Eastern coasts of England, in Essex, Norfolk, and Yorkshire, are principally occupied by diluvial cliffs of clay, with interspersed pebbles and blocks, and irregular layers of gravel and sand. These deposits cover large tracts in Yorkshire, Lincolnshire, Norfolk, Suffolk, Essex, &c. In the Midland Counties, gravel, containing in some places abundance of chalk flints, and in other situations pebbles from the Lickey Hill, is very common, and particular valleys quantities of oolitic gravel. It is generally observable that the most abundant portions of the deposits may be traced to the neighbouring ranges of hills, as the chalk of Holderness, Faldingworth, and Huntingdon, to the neighbouring wolds, the sandstones of the vale of York to the Western moorlands, and the quartz pebbles of Warwickshire to the Lickey Hill, but with them generally lie fragments from more distant sources.

Animal population at the time,

We now proceed to inquire what was the condition of the land over which the diluvial currents flowed, with respect to its animal population. That it was inhabited, and very extensively so, in many districts wasted by these floods, is evident from the really immense quantity and variety of bones of quadrupeds lying in gravel pits, clay cliffs, and other diluvial accumulations, or buried in caverns during and previous to that period of convulsion.

To mention all the known localities for diluvial masses from which bones of elephant, rhinoceros, horse, ox, deer, and a variety of other quadrupeds have been obtained, would be to form a gazetteer of Europe, Siberia, and North America. There is hardly a County in England where some remains of this kind have not been obtained at many places, and they are equally abundant in France, Germany, Italy, &c.

Exactly as at the present day the bed of a river envelopes the shells that perish in its waters, with the bones of animals accidentally lodged there, so the diluvial floods buried in the detritus of the land remains of the then existing organized creation. These remains enable us to say what races of animals were living upon the Earth at and previous to the time when those parts of it were overwhelmed; and if upon examination it be found that these animals were of peculiar types of conformation, that they did not begin to exist till a certain epoch, nor continue to live after another epoch, the period of their existence is a *zoological era* as distinct as any other disclosed to us by examination into the long series of periods during which organic beings have existed upon the Earth.

In illustrating this magnificent subject from the materials furnished by the researches of Cuvier and Buckland, we shall first present the evidence furnished by diluvial gravel, clay, sand, and other unquestionable deposits of the turbulent era alluded to; and afterwards add some results deducible from examination of caverns, the period of the occupation of which will be naturally determined by comparing their zoological contents with those of gravel pits, &c.

The following are some of the animals that have been discovered in these diluvial deposits.

Pachydermata.

Elephas primigenius.	Rhinoceros tichorhinus, &c.
Mastodon maximus, &c.	Tapir giganteus.
Hippopotamus major.	Sus fossilis.
Chœropotamus.	

Solipeda.

Equus fossilis.

Ruminantia.

Cervus euryceros, &c.	Urus.
Bos.	Merycotherium Sibericum.

Carnivora.

Felis spelæa, &c.	Vulpes spelaearum.
Hyæna spelæa, &c.	Ursus cultridens.
Wolf.	spelæus.

Rodentia.

Porcupine.	Arvicola.
Beaver.	

Edentata.

Megalonyx.	Manis giganteus.
Megatherium, two species.	

Mostly congenerous with those now living;

The most striking general inference derivable from inspection of the preceding and more extended lists, as contrasted with all the catalogues of the earlier animals, is the almost complete identity of the genera with some of those which now exist. Even in the tertiary system, though the quadrupedal population of Europe had become considerable, and the circumstances of their existence in several respects closely analogous to what obtain at present, the genera were for the most part wholly different. Here they are for the most part the same.

The species, however, of the zoological era under consideration were mostly different from the existing races, some of greater magnitude, others of different proportions, all distinguishable by more or less remarkable peculiarities of their bony remains. Yet these distinctions are often minute, and unless the question of the amount of possible change induced on the animal frame by long time and varying circumstances could be more exactly appreciated, it may perhaps always admit of a slight doubt whether the distinctions alluded to be characteristic of the species of animals, or of the circumstances of their existence. However, for all purposes of geological induction, the distinctions being constant are assumed to be specific.

Among the species found in caves, fissures, and breccia, referred to the same era, are the following.

Pachydermata.

Elephas primigenius, &c.	Chœropotamus.
Hippopotamus major	Sus fossilis
Rhinoceros tichorhinus, &c.	

Solipeda.

Equus fossilis.

Ruminantia.

Cervus euryceros, &c.	Bos, urus, antilope.

Carnivora.

Felis spelæa, &c.	Wolf.
Hyæna spelæa, &c.	Fox.
Polecat.	Ursus spelæus.
Weasel.	cultridens, &c.
Gulo spelæus.	

Rodentia.

Arvicola fossilis media.	Lagomys, &c.
minor.	Hare, rabbit, &c.
Rat.	Beaver.

From the general analogy between these two lists, from the prevalence in each of elephants, rhinoceros, hippopotamus, felis, hyæna, and bears, in Countries where at present not a single animal of such genera is known to exist, there seems every good reason to admit them as belonging to the same zoological era, which M. Omalius D'Halloy has, not inconveniently, called the mastozootic era. But all investigations concerning gravel and other diluvial deposits, prove indubitably that this era is exactly that which ended with the diluvial system of deposits. We may, therefore, venture in the following investigations to class together the remains of mammalia found in caves, fissures, breccia, gravel, clay, &c. as characteristic of a period of some duration, terminated in each district by great inundations, and equally capable of furnishing evidence concerning the then state of the Earth. It is not meant by this arrangement to pronounce at all concerning the question, yet very insufficiently examined, of the partial contemporaneity of the palæotherian and mastozootic races of animals in Europe.

Lived in Countries where their bones are found.

The first general result which we shall venture to draw from this combined evidence is, that the animals whose remains are found in diluvial gravel and other superficial accumulations, or in limestone caves and fissures, or in ferruginous breccia, lived near or on the spots where their bones are found. This important inference might be safely deduced from the ordinary circumstances under which fossil bones are found in superficial gravel, &c., since in these cases they are little worn, though lying amongst fragments of rocks rounded to pebbles, and often remain entire, or with no other injury than that occasioned by the effects of the atmosphere. Thus, the horns of a stag, scarcely in the smallest degree injured, have been obtained from the diluvium of the vale of Pickering, the long tusks of an elephant from that of Holderness and Essex. This conclusion might, perhaps with equal certainty, be rested upon the occasional finding of the bones of elephants and rhinoceros, and other "antediluvian" species, in marl pits under gravel, in company with shells now existing in the neighbourhood, of which some indications occur in Cuvier's celebrated Work the *Ossemens Fossiles*, and a more distinct case, at Market Weighton in Yorkshire, has been recorded by Mr. Dikes of Hull, and several members of the Yorkshire Philosophical Society. For in this case the bones of extinct and the shells of existing species of animals lay pellmell together, and the native locality of one must inevitably be ascribed to the other.

But the case becomes certainly stronger, when we take into view the history of the caverns, fissures, and breccia, containing bones; for these afford us not only reason to conclude that certain animals lived in definite regions at a particular era, but display many of their habits of life and accidents to which the nature of the country exposed them. Those who desire to follow at length the detailed history of caves and osseous breccia must be referred to the luminous pages of Buckland, (*Reliquiæ Diluvianæ*,) and that imperishable monument of genius, the *Ossemens Fossiles* of Cuvier. We shall here present a simple analysis of the leading *results* of their inquiries bearing on the subject before us.

Caverns and fissures containing bones, however preserved, and of whatever kinds these are, present some important characters in common.

Ossiferous caverns, how situated.

(1.) In the first place they are, we believe, always situated in limestone, very generally in stratified limestone, though this character is sometimes denied to the dolomitic limestone of the Mediterranean shores. This circumstance has, however, apparently no relation whatever to the accident of the caves containing bones, but is merely a general fact characteristic of limestone; for in this kind of rock nearly all the caverns, grottoes, and remarkable natural fissures in the World are situated. And as far as we have observed, there is no reason whatever in speculations on the *origin of the bone caverns and fissures* to exclude those of similar forms in which no bones occur.

(2.) This being the case, we may remark further, that though in some cases the existence of the cavern may be thought to be connected with dislocations of the strata, as at Greenhow Hill in Yorkshire, yet this is rather the rare exception than the general rule. The carboniferous limestone is full of caverns, yet not more so where numerous slips and veins divide it than in other places. Veins of lead ore hardly ever lead to these caverns, and it is a matter of general remark, that though the strata may be disturbed near them, the disturbance has little to do with the caverns.

(3.) Most caverns, whatever be the character of their floor, assume at intervals along their length, the appearances of a great fissure in the rocks. This circumstance must have been often observed by those familiar with the caves of Somersetshire, Derbyshire, and Yorkshire, and is recognised even in that least favourable example, Kirkdale Cave, which in its nearly level course keeps its floor nearly on one particular bed of the rock, but occasionally opens upwards into narrow irregular expansions or fissures. The fissures filled with breccia may, in fact, be often regarded as exposed caves, and resemble them in all essential circumstances.

(4.) Very few of these cavities in the rocks are entirely free on their sides and roof from remarkable depressions and cavities, like those produced on limestone by currents of water, or the slow consuming agency of the atmosphere. Many of them which now convey water, and are not incrusted with stalagmite, as the Peak Cavern in Derbyshire, show this sort of watery erosion so strongly as to impress most beholders with a conviction that the whole was excavated by the running stream.

(5.) Several writers, in particular Brongniart, have attempted to show that mere water has no effect in eroding rocks. This may, perhaps, be true of the *oxide of hydrogen*, but is certainly not a correct account of the effect of common water, and particularly of *water containing carbonic acid*, and traversing limestone rocks. The innumerable petrifying springs of limestone Coun-

tries at once demonstrate the inaccuracy of this reasoning. The very rain from the heavens eats away these stones rapidly. The springs which issue from limestone generally contain carbonate of lime, and most of them yield a large quantity of free carbonic acid upon exposure to the air.

How formed.

(6.) Those accustomed to underground works know it as a familiar fact, that the water which is absorbed by dry limestone land, takes particular channels through the rocks, down the joints, and along certain fissures. Every limestone hill in the carboniferous district of the North of England, shows in its *swallows* and *moor pits* the erosive power of the atmospheric water. We shall, therefore, venture from all these considerations to maintain the enlargement or excavation of these caverns to be principally owing to the subterranean passage of water charged with carbonic acid, the direction of this water, and its power of erosion, being favoured by fissures and other causes. If the altered drainage and other circumstances of a country so far change the course of the water as to leave these subterranean channels almost dry, the small quantity of moisture continuing to arrive, may slowly deposit stalagmite over the surfaces formerly eroded, and the cave change its appearance altogether. An accidental inrush of water from another source may deposit mud or pebbles, and this be also covered up by another layer of stalagmite.

It is no great objection to this view, that the cavities are sometimes exceedingly irregular, for water in its subterranean course must follow the original cracks of the rocks. Indeed, upon a review of this matter, that very irregularity may perhaps be thought an argument in favour of the mode of origin here suggested.

The most remarkable ossiferous caverns in England are Kirkdale Cave near Kirby Moorside in Yorkshire, the Dream cavern near Wirksworth in Derbyshire, Banwell Cave in the Mendip Hills, Kent's Hole near Torquay, Oreston near Plymouth, and Paviland near Swansea; in Germany, the slopes of the Harz mountains give us the caves of Baumann, of Biel, and of Schwarzfeld. Between the Harz and Franconia is the Bear Cavern of Glucksbrunn; the Jura formation near Baireuth is celebrated for the rich associated caverns of Gailenreuth, Schænestein, Brunnenstein, Holeberg, Wieserloch, Geissloch, Wunderhohle, Rabenstein, Kuhloch, Zahnloch, Schneiderloch, Rewig, &c. In Westphalia the same oolitic formation has the caves of Kluterhohle, and Sundwich. The Caves of Adelsburg in Carniola and the Dragons' Caves in Hungary have also yielded bones. In France, instructed by Dr. Buckland's researches, two caverns, rich with bones, have been described by M. Thirria near Vesoul, and several others near Montpellier and Narbonne by Marcel de Serres, Tournal, Christol, &c. and one near Miremont by M. de la Noue.

Osseous breccia appears singularly connected with the coasts of the Mediterranean. It occurs at Gibraltar, in Languedoc, and at several other points in the South of France, at Antibes, Nice, Pisa, Cape Palinurus, North of Bastia, (Corsica,) Cagliari, (Sardinia,) Maridolce, (Sicily,) in Dalmatia, Aragon, &c. Ferruginous breccia, in which bones are associated with pisolitic iron ore, occurs in Wurtemberg, and in Carniola in Jura limestone.

How filled with bones.

In some of these caves hyænas lived and dragged into them for food the bones of other animals existing in the vicinity; bears died in others; some were filled by the accidental falling in of browsing quadrupeds, and others heaped with a mixture of bones, mud, and pebbles brought by general or local floods on the surface. We shall give an abstract of the characteristic facts attending each of these cases.

Kirkdale Cave.

Kirkdale Cave is one of the most remarkable instances of ossiferous cavities known in England, both from the number of species and abundance of the bones of quadrupeds found there, their state of conservation, and other attendant circumstances. The entrance of this cave is on the side of a narrow valley 30 feet above the stream in a nearly level and perfectly undisturbed bed of coralline oolite. It had a sort of vestibule, much larger than the interior windings of the cave, and in this, according to Mr. Salmond, lay a considerable proportion of the large bones of elephant, rhinoceros, &c. Beyond this was a STEP in the floor of the thickness of one bed of limestone, leading to the interior recesses, which follow an irregular line, occasionally rising to the height of 14 feet, but generally under 4 feet, and about the same breadth, but liable to contractions in both their measures. The floor was generally overspread and its inequalities filled up by a layer of mud, of calcareo-argillaceous substance, such as might be supposed derivable from the joints and partings of the limestone. In some places the mud was more coarse and sandy. Stalagmite in considerable quantity had dripped from the roof, incrusted the sides, and covered like a sheet the layer of mud rising upon its surface into mamillary tubercles.

In the mud, and protruding occasionally through its stalagmitic covering, lay the bones of six or seven *carnivora*, hyæna, tiger, or lion, bear, wolf, fox, and weasel; three *pachydermata*, *viz.* elephant, rhinoceros, hippopotamus, the horse; four *ruminantia*, ox, and three kinds of deer; four *rodentia*, hare, rabbit, water rat, mouse; beside five birds, raven, pigeon, lark, duck, and a bird of the size of a thrush.

The bones were scattered over this long area, "as over a dog kennel," almost universally broken to pieces, not as if by common fracture, but by violent biting and gnawing: marks of teeth are discernible on many, exactly like those left by living hyænas on similar bones submitted to their jaws. Hyænas' teeth in great numbers, of all ages, milk teeth, shed teeth, and worn to stumps in the jaws of the animal, abounded in the cave, besides a considerable quantity of osseous fecal matter, like that of the modern hyæna. From these data, most of which may be verified on the numerous specimens extracted from the cave, Dr. Buckland infers, that hyænas were for a long period the undisputed tenants of this den, lived in it for many generations, dragged into it for food, piecemeal, the bodies of animals then living in the neighbourhood, and were finally dispossessed of their hold by an irruption of water which let fall the muddy sediment now enveloping the bones. The ordinary action of the water passing through the calcareous rock then covered the whole with stalagmite, and closed up the bones from the destructive agency of moisture and air. This accounts for the conservation of their gelatine. Few conclusions of this precise nature appear better supported by the facts of the case, and when we reflect on the remarkable analogy, in almost all points concerning the state and conservation of the bones, of the cavern at Torquay called Kent's Hole, and contrast these particulars of the *hyæna dens* with those of the *ox caves* in Mendip, we shall feel a full conviction that Dr. Buckland's bold theory is a true interpretation of Nature.

The caves of Franconia appeared to Dr. Buckland to have been tenanted by bears which died in the retired parts, and were there mixed more or less with sediment and pebbles brought by subsequent diluvial floods, and the whole covered over by a stalagmitic crust formed in the usual way. The cavern of Gailenreuth is perhaps the most magnificent example of this doctrine; but that at Kühloch presents some peculiarities of a very interesting kind. "It is literally true that in this single cavern (the size and proportions of which are nearly equal to the interior of a large church) there are hundreds of cart-loads of black animal dust entirely covering the whole floor, to a depth which must average at least six feet, and which, if we multiply this depth by the length and breadth of the cavern, will be found to exceed 5000 cubic feet. The whole of this mass has been again and again dug over in search of teeth and bones which it still contains abundantly, though in broken fragments. The state of these is very different from that of the bones we find in any other caverns, being of a black or more properly speaking dark umber colour throughout, and many of them readily crumbling under the finger into a soft dark powder resembling mummy powder, and being of the same nature with the black earth in which they are imbedded. "The quantity of animal earth accumulated on this floor," continues Dr. Buckland, "is the most surprising and the only thing of the kind I ever witnessed; and many hundred, I may say thousand individuals must have contributed their remains to make up this appalling mass of death. It seems in great part to be derived from comminuted and pulverized bones; for the fleshy parts of animals produce by decomposition so small a quantity of permanent earthy residuum, that we must seek for the origin of this mass principally in decayed bones. The cave is so dry that the black earth lies in the state of loose powder and rises in dust under the feet: it also retains so large a proportion of its original animal matter, that it is occasionally used by the peasants as an enriching manure for the adjacent meadows." This cave is entered by a lofty arch, above the river Erbach, expands within both in height and breadth, and terminates in two chambers closed at the end. No fissures enter this cave, and it has no other exit than the entrance above named, except a very small passage to the same valley. These circumstances are considered by Dr. Buckland to explain the absence of diluvial accumulations in this cave. There is no appearance of either stalagmite or stalactite having ever existed in this cavern.

Cave of Kuhloch.

Mendip

Dr. Buckland's views concerning the ancient occupation of hyænas and bears of the caves of Kirkdale and Franconia, derive much elucidation from the discoveries of other caverns in which the animal remains appear to have been accumulated in a different manner. We shall mention those of Hutton in the Mendip Hills, and of Ouston near Plymouth; the former disclosed by ochre works, the latter by quarrying for limestone. The ochre of Mendip Hills appears, in some cases, to be derived from the decomposed strata of the vicinity, and deposited in caves and fissures of the limestone, either by water continually passing downwards by filtration, or by some more transient and violent operation. In pursuing one of these mines of ochre near the village of Hutton, bones of many animals were discovered, and the circumstances were examined by the Rev. Mr. Cutcott, from whose manuscript Mr. Conybeare has drawn up a clear account of this remarkable occurrence. The elevation of the ochre pit was 300 to 400 feet above the sea. "The ochre was pursued through fissures in the limestone occasionally expanding into large cavernous chambers, their range being in a steep descent and almost perpendicular. In opening the pits the workmen, after removing 18 inches of vegetable mould and 4 feet of rubbly ochre, came to a fissure in the limestone rock, about 18 inches broad and 4 feet long. This was filled with good ochre, but contained no bones: it continued to the depth of 8 yards, and then opened into a cavern about 20 feet square and 4 high; the floor of this cave consisted of good ochre, strewed on the surface of which were multitudes of white bones, which were also found dispersed through the interior of the ochreous mass. In the centre of this chamber a large stalagmite was suspended from the roof, and beneath a similar mass rose from the floor almost touching it; in one of the side walls was an opening about 3 feet square, which conducted, through a passage 18 yards in length, to a second cavern 10 yards in length and 5 in breadth, both the passage and cavern being filled with ochre and bones. Another passage, about 6 feet square, branched off laterally from this chamber about 4 yards below its entrance; this continued nearly on the same level for 18 yards; it was filled by *rubbly ochre, fragments of limestone, and lead ore confusedly mixed together; many large bones occurring in the mass*, among which four magnificent teeth of an elephant were found. In the second chamber, immediately beyond the entrance of the branch just described, there appeared a large deep opening, tending perpendicularly downwards, filled with the same congeries of rubble, ochre, bones, &c: this was cleared to the depth of 5 yards; this point being the deepest part of the workings was estimated at about 36 yards beneath the surface of the hill." (*Reliq. Diluv.*) The bones found in Hutton Hole belong to elephant, rhinoceros, ox, horse, deer, hyæna, bear, a nearly complete skeleton of a fox, hog, and some gnawing animal.

Oreston Caves.

Three deposits of bones at Oreston, near Plymouth, have been detected by Mr. Whidby during the removal of the entire mass of a hill of transition limestone for the construction of the Breakwater. The first deposit (1817) lay in a cavern 15 feet wide, 12 high, and 45 long, and about 4 feet above high-water mark. This cavern was filled with solid clay, in which teeth and bones of rhinoceros were embedded. The second discovery (1820) was of a smaller cavern, distant 120 yards from the former, one foot high, 18 wide, and 20 long, and 8 feet above high-water mark. But the greatest extent of subterranean cavities was exposed in 1822, by the intersection of apertures in the middle of the limestone, containing an immense deposit of bones and teeth imbedded in clay. Dr. Buckland describes in a very graphic manner the irregular branching or insulated fissures and caverns which were at this time laid open in an artificial cliff 90 feet high, their various direction, loamy contents, and relation to similar cavities not containing bones in the neighbouring limestone cliffs. He remarks that the fissures and caverns are so connected, so often confluent and inosculating with each other, and so identical in their contents, that there appears to be no difference as to the time and manner in which they were filled. In many of those which are nearly vertical, the communication is obvious, but those which pass obliquely, and consequently seldom lie in

the plane of the cliff, may *appear* to close upwards. In almost all the cavities there occurs a deposit of mud and sand, and angular fragments of limestone; these substances sometimes entirely fill up the lower chambers, and are lodged in various proportions on the shelves and ledges and in lateral hollows of the middle and upper regions. In one large vault it is sorted into laminæ; sometimes it is interspersed with extraneous fragments of quartz and clay slate; stalagmite sometimes invests it; in some few spots were balls of iron-stone, and concretions of ochre formed in the clay; in others was a considerable quantity of manganese ore, sometimes in concentrically coated balls. The bones collected in the Oreston caverns and fissures belong to hyæna, tiger, wolf, fox, horse, ox, deer. The bones of the horse predominated; those of ox and deer were also abundant.

We may admit, without hesitation, that these caverns and fissures at Oreston were filled with this mingled mass of earthy, stony, bony, and metallic matters, by aqueous action; and there seems no good reason to doubt that partly in this manner, and partly by the accidental falling of quadrupeds into open fissures of the limestone, many other caves in Somersetshire, Derbyshire, &c. have been stored with their animal remains.

Osseous breccia of the Mediterranean.

From such cavernous fissures, filled with mingled fragmentary masses, as those of Oreston, there is hardly a step to the fissures or caves containing ossiferous breccia at so many points around the Mediterranean Sea. Almost every limestone rock, wherever its interior structure can be seen on the sea-coast, in ravines, in mines, is found to be traversed by fissures and excavated in caverns: it was therefore to be expected that such should be exposed in abundance in the calcareous precipices of the Northern shore of the Mediterranean. But it is very remarkable that they should be in those regions so generally productive of bones; that these should so generally be found in a reddish-coloured loamy breccia, holding fragments of the neighbouring rock, helices, and other spoils of the land; and that no marine production whatever should be found mingled with the mass, though, as at Santo Ciro, near Palermo, (*Geological Proceedings*, 1833,) there be proofs of the marine submersion of the actual cave, before the introduction of the bony breccia. There is clearly no necessary relation between the existence of these ossiferous cavities and the proximity of the sea; in many cases their exposure may be owing to the waste of the coast, but in others it must be mainly ascribed to the convulsive elevation of the land at some ancient period. In all cases the production of caverns and fissures in the rocks is the work of causes acting during periods long anterior to those when the animal remains were introduced. Thousands of cavities have been produced in the rocks, and filled with mineral treasures, and buried beneath vast depths of consolidated strata, of very high antiquity; such of them as were by any causes exposed at the surface, have been filled with clay, or heaped with fragments of rock, and in the great majority of instances lined with calcareous spar, and in Countries which were then inhabited by quadrupeds some have been partly filled by bones. The Geological era, when the latter occurrence happened, is rendered definite only by a rigid anatomical examination of the bones; and by this Cuvier has taught us that we may confidently refer the great majority of the quadrupedal remains, whether found in gravel on the surface, in the mud, gravel, breccia, or stalagmite, or on the naked floor of subterranean caverns, to one zoological period. In general, the most abundant remains in the ossiferous breccia of the Mediterranean shores belong to the orders ruminantia and rodentia; bones of ursine, feline, and canine animals, as well as those of hippopotamus and elephant, are rare. This is exactly what should happen upon the supposition that the bones in the fissures were derived chiefly from animals which fell into them, for these naturally should consist principally of herbivorous tribes. The presence of land shells, of fragments of the neighbouring rocks, the abundant interlacement of stalagmitical carbonate of lime, tends exactly to the same conclusion; and even the redness of the breccia of Gibraltar, Cette, &c., is probably owing to the ferruginous nature of the neighbouring rocks. The influence of local causes is thus clearly indicated, and in the opinion of Cuvier, these have operated through considerable periods, so that the bones and fragments of rocks fell successively into the cavity, and the calcareous cement was gradually accumulated. If, in addition, we suppose, with Dr. Buckland, that these same cavities have since undergone the action of moving water, which might drift in heaps the fragmented bones and stones, and mix with them loam and occasionally pebbles, all the phenomena seem naturally explained, and the theory of the ossiferous breccia becomes connected with that of the proper cavern deposits. For particulars respecting the ossiferous breccia of Gibraltar, Cette, Antibes, Nice, Pisa, Cape Palinurus, Corsica, Sardinia, Sicily, Dalmatia, Cerigo, Aragon, and the Veronese, we must refer to Cuvier's admirable *Ossemens Fossiles*, tom. iv.

Climate of the Northern regions in the Elephantoidal era.

As from the facts previously related, no doubt whatever can remain that in the "diluvial" period, and for a long time previous, there existed in Europe elephants, rhinoceros, hippopotamus, lions, and hyænas, besides bears, the glutton, wolves, foxes, the horse, oxen, the urus, deer, beavers, hares, rabbits, water-rats, &c., we are presented with a problem of considerable interest relating to the state of the climate at that period. The most abundant, perhaps, and most generally diffused of all these remains are those of the elephant and rhinoceros; though in particular cases, bears or hyænas fill whole caves, and the horse, ox, and urus are very plentiful in gravel and marl. So many animal remains of genera now exclusively confined to hot climates, have induced many Geologists to conclude that the Northern regions of the Globe were at that time much hotter, and that their total extinction was occasioned by a sudden refrigeration of the climate. On the other hand, the glutton, the urus, wolves, foxes, bears, horses, and large horned deer, and beavers, appear as characteristic of cold or temperate climates, and furnish arguments for the doctrine that the animals resembling those now living in tropical regions, were fitted by some peculiarity of constitution to support the rigours of the Northern zone. These statements are so equally balanced, and the authors who support them so respectable, that no impartial inquirer can pronounce between them without further evidence. This evidence must be of a particular kind. It will be of little use to add to the number of animals on either list; and as the *species* are *different* from those now in existence, the relative power of adaptation to climate of their several living analogues will not be sufficient to settle the point. We must find the remains of some of these animals, in such condition, or accompanied by such collateral circumstances, as to characterise the climate independently of the generic relations of the animals.

Geology. Ch. II.

Evidence in this subject.

Two cases coming within these conditions are known to Geologists, of so distinct a kind, and leading so positively to the same conclusion, as to leave little room for further discussion. The first is the instance of an elephant, of the same species precisely as that usual in diluvial accumulations, being found in 1804, enclosed in solid ice, at the mouth of the Lena, where that Siberian river flows into the Arctic Sea. It was a perfect animal, with tusks in the jaws, and had evidently been entombed in its icy sepulchre immediately after death, for the flesh of its huge body was not decayed, but actually furnished a feast to the wolves and bears of the coast; the skin remained entire, and its whole surface was covered with *hair of two kinds*, one shorter and finer near the body, the other coarse and bristly, and even sixteen inches long. It is to be regretted that the difficult circumstances of the country did not permit Mr. Adams to examine minutely the anatomy of this specimen, thus wonderfully preserved through the fluctuations of ages; but the skeleton, mounted at St. Petersburg, furnishes sufficient characters to prove its perfect agreement with the fossil, and its distinctness from either of the living elephants. Here then is a plain proof that the fossil elephant was fitted, by an appropriate clothing, to withstand the occasional cold of a high Northern latitude, not perhaps to exist on the shores of the Icy sea, but to inhabit about the sources of the Siberian rivers, and over the whole extent of Europe and a part of North America. The North coast of America, as well as that of Siberia, encloses abundance of the remains of these elephants in cliffs of frozen mud. (Capt. Beechey.)

The conclusion from this fact is rendered still more decisive by the discovery, in 1770, of the fossil rhinoceros tichorhinus, under the same extraordinary circumstances of preservation of flesh, on the banks of the Wiluji, which falls into the Lena below Jakoufgk, and its body was likewise *covered with hair*.

Dr. Buckland's conclusion of some remarkable catastrophe and sudden refrigeration of the Siberian regions and the borders of North America, near Behring's Straits, seems to offer a reasonable explanation of the extraordinary preservation of these remains, which besides may have been drifted from their original seats Northwards.

The second case is the discovery together in the same marl pit, connected with gravel deposits, near Market Weighton, in Yorkshire, of the remains of elephant, rhinoceros, lion, wolf, horse, urus, ox, deer, &c., species all or nearly all extinct, with thirteen species of land, marsh, and fresh-water shells now living in the neighbourhood. Now as hardly any animals are more remarkably limited in climate, and restrained by local circumstances, than the molluscous tribes of the land and fresh waters, as the number of the species here discovered is considerable, and their identity altogether certain, without a single extraneous species, it is a safe conclusion, that the climate in which they lived was that which England and the central parts of Europe now enjoy; for such mollusca become mixed with other races on approaching the Mediterranean, and many of them cease to exist in the colder latitudes of Northern Europe. The same conclusions result from the examinations of that remarkable deposit called "Loess," in the valley of the Rhine, where the extinct elephants and rhinoceros lie with many existing land shells. (Horner.) Hence we conclude, with confidence, that the antediluvian climate of the Northern parts of the Globe was nearly the same that it is at present; and it is no great objection to this view, that the banks of the Frozen Sea will not now feed an elephant, because, in the first place, it is not yet proved that the elephants were not drifted by the long Siberian rivers to their frozen mouths: and secondly, our conclusion is for a temperate or cold, not frigid climate, as distinguished from the torrid climate, to which some Geologists would unmercifully subject these animals in their warm Winter dress.

Geology. Ch. II.

Nearly all the propositions that we have endeavoured to establish concerning the important subject of diluvial accumulations will be admitted by theorists of every order. That the Earth has been covered over a large extent, since the completion of nearly its whole apparent series of successive marine formations, by tumultuous floods of water, powerful enough to dislodge and transport, hundreds of miles from their native sites, huge blocks and fragments of rocks, and to destroy the races of animals then living in those Countries, and to produce considerable changes in Physical Geography, is a fundamental doctrine of modern Geology. But questions of considerable difficulty, which might perhaps have been postponed to a later period of the investigation, if the Science had been permitted to follow its own secure course of observation and induction, are forced upon our attention by the anticipations of theory, and the premature anxiety felt, even by writers on Geology, to establish parallels of time between the Geological datum of the destruction of certain land-animals and the Noachian Deluge.

Other problems.

We have shown that these diluvial floods were very extensive, but we are required to answer further whether they were *universal*. We have proved them to have belonged to a certain limited zoological era; but we are asked, were they *simultaneous* over the globe? We have admitted that they have effected changes in the physical features of the Earth's surface, but we are called upon to state whether *valleys* were excavated by their agency.

This is the place to discuss the two former questions; the latter, though often mixed up with the others, will admit of clearer solution by first examining the action of existing causes in modifying the surface of the Earth.

Extent of the phenomena.

The doctrine of the *universality* of the diluvial currents, was adopted by Geologists, according to their interpretation of the connection between Geology and the Hebrew Scriptures, long before they had acquired the power of clearly tracing the effects of such currents across their own hills and valleys; and after Mr. Smith had fixed some of the leading characters of the diluvial detritus in England, they were hastily, by anticipation, applied even to Countries never visited by any observer. Subsequent researches have to a certain extent justified this boldness; and the discoveries of Buckland and Cuvier, by fixing zoological characters for the diluvial periods, have harmonized the results into a system. But it is unsafe at present to venture such a doctrine as the universality of the diluvial currents, even upon the admission that their powerful traces are recognised over nearly the whole Northern hemisphere. If, indeed, it should eventually be proved, that diluvial currents have constantly followed upon the elevation of large tracts of land above the sea, their universality might be safely inferred, since nothing can be more clear than the former submersion of all our continents. But this would not satisfy all the conditions of the problem; as in diluvial gravel and caverns so closed there would be no reason to expect the bones of land-animals, and it is a matter of notoriety that the elevation

of land above the sea, instead of being confined to the mastozootic era, has proceeded at intervals through the whole Geological period.

It must, indeed, be owned that many mountain ranges were uplifted at the periods alluded to, but we dare not so far deviate from the method of observation and induction which has raised Geology to its elevated rank among the Sciences, as to assume universal inundations of the Globe, to follow confessedly partial disturbances of the bed of the Ocean. On this, as on many other questions, we must appeal to further observation.

Length of the diluvial period.

The doctrine of *simultaneity* of diluvial currents over the Globe, was introduced by the same desire to accommodate Geological theory to the ordinary interpretation of the Mosaic record, and involves considerations of great difficulty. To determine whether diluvial phenomena are traceable over a greater or less extent of the surface of the Earth is the work of observation. To settle the date of these phenomena with reference to one another is a very nice and difficult subject of analysis and inference. Even if it were the fact that the diluvial detritus in different Countries was scattered by the devious currents of one simultaneous inundation, it is doubtful whether satisfactory Geological evidence could be collected to *prove* this. No single deluge of such vast extent has been disclosed by investigations of the phenomena of earlier date; we see no agencies, either cosmical or terrestrial, likely to occasion it now; it cannot, therefore, be *assumed*, as a natural phenomenon, without violation of the rules of Philosophy.

But though, strictly speaking, the question of the simultaneity of the diluvial catastrophes in different regions is inadmissible in the present state of our knowledge, we may modify the inquiry so as to bring it within the scope of examination. Let us inquire if the diluvial phenomena of all Countries in which they have been observed, have so much of a common character as to point to the same *kind* of cause, so much of a common direction as to be assignable to causes having the *same local origin*, and are accompanied by such collateral circumstances as to be limited within *an assignable period of time*. The first point is already answered in the affirmative by all the preceding observations; on the second point, we may observe that a considerable number of observations indicate a prevalent direction of currents from the North, but many others appear to refer the local origin of the currents to the neighbouring mountains. The third part of the inquiry has also been met in part by the history of the animal remains in the diluvial and antediluvial deposits; for these clearly belong to a limited zoological period, and as this period appears to have been terminated in each district by the diluvial catastrophes, we are justified in believing that the time during which these turbulent waters flowed was comparatively short. To the same conclusion we must necessarily arrive, from a comparison of the diluvial disturbances with those of older Geological periods.

But short as this period was, we are able to divide its characteristic phenomena into successive stages. There are few parts of England, where the diluvial masses do not consist of more than one kind of deposit, derived from a current in one direction. On the coast of Yorkshire the general base of the whole diluvium is a thick mass of clay, with heaps of fragments of rocks derived from Cumbria and North-Western Yorkshire scattered through it. In some places this rests upon water-moved chalk and flints; in others it is surmounted by beds of gravel and sand, which are themselves, near Bridlington, covered by thick layers of chalk and flints from the neighbouring wolds. But we must be careful not to infer from this and similar facts more than they will bear. The lapse of time is here proved, but as no deposit intervenes implying that the time was considerable, as the lower diluvium is not water-furrowed to admit the upper, as the same characteristic animal remains are found in several portions of the deposit, it is possible that all these successive diluvial masses might be brought by the varying impetus of one continuous or intermitting general convulsion. De Beaumont, from his admirable survey of the Alps, infers with great probability that the diluvium around these mountains belongs to two distinct periods, and was occasioned by two separate convulsions affecting the Alps. By the former convulsion, which elevated the Western Alps from Dauphiné to Mont Blanc, prodigious quantities of débris rolled off to the West, and by the second convulsion, which elevated the Eastern Alps from Mont Blanc to Vienna, the old diluvium was dislocated, and floods were occasioned, which transported a great quantity of materials over the detritus of the former period. Here, also, we must be cautious in the inference. That *some intervals* happened amidst the diluvial disturbances, that the diluvium is of *unequal antiquity* is clearly proved; but nothing has yet been established contrary to the general view of this subject, which we have before suggested, *viz.* that the diluvial phenomena were produced during *a comparatively short period* of convulsion of the land, and consequent agitation of the sea, ensuing upon the completion of all, or nearly all the marine strata, now apparent above the sea, and subsequent to the habitation of at least the flatter regions of the Earth by various races of quadrupeds now extinct. This is all that can be safely asserted in the present state of Geology.

Geological monuments of the existence of Man.

In all the periods of time which elapsed during the formation of the stratified rocks, there is no evidence that Man was a dweller on this Globe. Not in the most recent of the tertiary strata, neither in the littoral nor in the lacustrine deposits of that period, have any traces of Man or his works been perceived. This ought in no degree to surprise us, for all the animals and plants of that and earlier periods were *parts of an earlier system* of organized nature. But it appears something extraordinary that bones of men and vestiges of human art should have been so rarely found in any of the ascertained deposits of the diluvial era, except under dubious or explanatory circumstances, since at that time the earth had assumed its present form and appearance, and was inhabited by races of quadrupeds which, if not specifically the same, were, for the most part, closely analogous to those which now live; in particular, the horse and domestic cattle, animals so singularly serviceable to and dependent on Man, existed in great plenty in the Northern zones, and, therefore, the *present system* of organized nature, of which Man is the head, may be said to have commenced.

That the bones of men are as durable as those of quadrupeds, is established by comparisons made on fields of battle, and, therefore, if he lived with the mastozootic quadrupeds, his remains should, under some circumstances or other, be found mixed with theirs. Dragged into a den by the prowling hyæna, or accidentally lost in a fissure, or overwhelmed by waves and buried in diluvium, we should frequently meet with the bones of our ancestors. Old writers, who saw in every

thing only the traces of a general deluge, are full of discoveries of the bones of *men;* but modern anatomy has assigned them to their true analogies, the *elephant, salamander*, and *saurian*. In modern times a few examples of bones of men, found under circumstances arguing great antiquity, have been recorded. Upon strict examination it appears that in most cases these remains belong to a later epoch than the diluvial convulsions: the petrified bodies of the coast of Guadaloupe are enveloped in comparatively recent accretions; the human remains of the valley of the Elster, near Leipzig, appear to have been inhumed since the general dispersion of diluvium; the woman found in Paviland cave was of an early British era. The only cases remaining for further examination are some caves in the South of France, where the remains of Man and rude pottery are found mixed with a quantity of bones belonging to extinct species of animals of the mastozootic era; superficial deposits in Baden and in Austria, where remains of men with depressed skulls (as if occasioned by unnatural bandages) are found; and the remarkable notices by M. Boué of mingled human and animal remains in the breccia of Nice and Dalmatia.

In South France.

Without stopping to discuss the yet imperfect evidence concerning the antiquity of these remains in the breccia and superficial accumulations, we shall pass to the consideration of the caves in the South of France. From the examinations of Tournal, Christol, and Marcel de Serres, a considerable body of evidence has been collected concerning the caverns of Bize, (Aude,) Durfort, Pondres, Souvignargues, (Gard,) and from the similar state of conservation as well as mixture of the bones of men and animals in the caverns of Bize, M. Tournal decides positively that their age is the same. These animals are stag, chamois, roebuck, antelope, and bear, which hardly require to be considered of the mastozootic era. The same conclusion was drawn by M. Christol, from subsequent researches in the caverns of Gard, in which the animal remains were decidedly of the same era as the fossil elephant and rhinoceros. But the most instructive, probably, of all these discoveries, is that of the cavern of Miallet, near Anduze, (Gard,) completely investigated by M. Teissier. This grotto, situated on the banks of the Gardon, is opened in a dolomitic rock subordinate to the lias, on a steep slope, thirty metres above the valley. The lower layer of the interior of the grotto is dolomitic sand, irregularly overspread by a thin stalagmitic crust, and in places by an argillo-ferruginous mud, more than a metre thick, and adhering in several places to the roof and sides. In this bed were discovered in great abundance, and excellent preservation, bones and teeth of large bears, and with them a few bones of hyæna, ruminantia, and birds; under the stalagmite, and under a bed of loamy sand from two to four decimetres, a great number of human remains was found in various parts of the grotto. In the depth of the cavern they are unquestionably mixed with the bones of bears, which predominate; towards the entrance, on the contrary, human remains are most abundant, and appear of less antiquity. Upon the ossiferous loam, under a little projection of rock, was discovered a human skeleton nearly entire, near it a lamp and small figure in earthenware; further off bracelets of copper; in other situations coarse pottery, wrought bones, and edge tools of flint, indicative of ruder industry. The human skulls were depressed from above, apparently by artificial means, thus presenting a deceptive resemblance to the negro, though really belonging to the Caucasian race of men.

M. Teissier infers from these data that the accumulation of distinct periods can be traced in this cave:—1. The mastozootic or antediluvian era of the bears, with whose remains those of men are mixed, perhaps by subsequent natural or artificial means. 2. The era of rude civilization, (probably Celtic,) when the coarse pottery, flint tools, &c. were introduced, perhaps, to grace the sepulture of individuals. 3. The era of Roman Arts.

There is no necessity of hazarding a definitive conclusion on the antiquity for these human remains, because there is very great probability of gathering much additional information by the discovery of new caves under different circumstances. In the mean time we may remark that the principal arguments for the coeval existence of men, and extinct pachydermata and carnivora in the South of France, is the intimate mixture and equal conservation of the bones; and these arguments should not be slighted, for they would, probably, not have been resisted in any case of the mixture of quadrupedal remains. On the other hand, the known facts that many parts of the Mediterranean shores were anciently possessed by Troglodytic nations, and that the custom of burying in caves, as well as retiring to them for safety, was very general in these Countries, adds great force to the opinion of M. Desnoyers, that, in most cases, the human remains are of no greater antiquity than the early Celtic Ages, in which very similar works of Art were executed. (See Desnoyers, *Rapport à la Soc. Géol. de la France*, 1831.)

It is clear that ossiferous caves have received their contents, some at one period, and some at another, and that in others operations of the same kind, repeated at very different periods, have consigned to our investigation monuments of all the great zoological changes which have happened on the dry land since it first became tenanted by mammalia. The whole subject must yet receive a great accession of well-observed facts. One remark, concerning the excessive rarity or non-existence of human remains in diluvium, and in caves of the elephantoidal era, may be of considerable importance. Those parts of the Earth's surface to which traditions and, perhaps, general reasoning, seem to point as the first sites of the human race, the central regions of Asia, have been as yet little examined with reference to this question. It may be very possible yet to discover them there even in abundance, though in the high Northern regions men may not have existed till much later periods. It is a singular fact that the Quadrumana or monkey tribes which, so nearly approach to the bodily organization of man, are equally absent from the deposits of which we are speaking.

Upon the whole, the evidence yet obtained concerning *the Geological period* when the human race began to exist on the Globe, is very imperfect, and we may, perhaps, wait long for more full information. In the mean time, it may be stated as a general admission that Man did not exist on the Globe during the secondary, and, probably, not during the epoch of tertiary formations, and that sufficient evidence for his coexistence in Northern climes with the mammoths and hippopotami is yet wanting; but as the races of oxen, horses, camels, &c. had then begun to exist, it is a reasonable expectation that, eventually, this question will be decided in the affirmative.

We shall conclude our remarks on this interesting

Cause of diluvial action.

class of deposits by some attempt to assign the causes of the diluvial phenomena. Those who refer these effects to one universal flood sweeping over the whole Globe, must of necessity ascribe such a mighty catastrophe to some great astronomical cause, such as the appulse of a comet, or the displacement of the axis of the Earth, or appeal to a miracle. But as we cannot venture to assume that what we name diluvial phenomena are of universal extent, or were occasioned by a single convulsion, nor are entitled at our pleasure to disturb the harmony of the Solar system, nor to help our ignorance by invocation of miracles, these conjectural hypotheses must be passed by in silence. From what has been previously stated, we are entitled to look upon the diluvial epoch as a short period of violent tumult in the ocean, like many which have happened before; perhaps more extensive, but certainly similar. Why, then, should we not refer it to the same causes? As the elevation of the beds of the sea after the grauwacke period, after the carboniferous period, after the cretaceous period, produced large and violent floods, and caused the formation of extensive conglomerates, so the elevation of the Alps may have caused the diluvium which has rolled from them, and the elevation of the Scandinavian chains may have caused the transport of their granites, sienites, and limestones across the Baltic, and along the plains of Germany. That the Alps have been elevated from deep sea is the universal conclusion of observers; that the whole chain has been raised at a comparatively recent period is certain; and there appears every reason to believe that the dispersion of the boulders was consequent upon the elevation of those parts of the Alps from which respectively they were detached.

We cannot apply this mode of reasoning to the Cumbrian mountains in England, for these appear to have been elevated above the sea at a far earlier epoch than that now under discussion. In this case, then, the effect must be ascribed to a *cause acting from a distance*, which would agree with the magnitude of the phenomena observed, and lead to the notion of some very general convulsion preceding the diluvial movements. Upon the whole, we will venture to conclude that the diluvial currents were occasioned by convulsive movements of parts of the solid fabric of the earth, of sufficient force to throw the waters of the sea over distant regions of dry and elevated land.

Table of Organic Remains in Caverns and Superficial Deposits subsequent to the Tertiary Period.

N. B. Extinct genera are marked with an asterisk. Caverns marked with (*c.*) Breccia with (*b.*)

Name.	In Caverns and Breccia of all Ages.	In Diluvial and Earlier Accumulations.
Remains of men	*c.* Gailenreuth, Zahnloch, Paviland, Bize, Durfort, Pondres, Souvignargues, Sicily	Kostritz, Rhine Valley, Austria, &c.
	b. Nice, Dalmatia.	
Vespertilio	*c.* Franconia, France	Köstritz.
	b. Cagliari, Antibes.	
Sorex	*c.* Avison.	
	b. Sardinia, Dalmatia	Ditto.
Talpa	*c.* Avison	Ditto.
Ursus spelæus, Blum.	*c.* Germany, France, England	Chatillon.
	b. Krain, near Krembs, Munster	
arctoideus, Blum.	*c.* Franconia, Bize, Sallèles, Lunel Vieil.	
cultridens, Cuv.	*c.* Sundwich, Kent's Hole	Val' d'Arno, Puy de Dôme.
other species	*c.* Franconia, Sundwich, Fouzan, Sallèles.	
	b. Perpignan	Puy de Dôme
Nasua, Cuv.	*b.* Nice.	
Meles vulgaris	*b.* Lunel Vieil, Sallèles.	
Gulo spelæus	*c.* Gailenreuth, Sundwich.	
Viverra, Clift	*c.* and *b.* Australia.	
Canis spelæus, (Wolf.)	*c.* Franconia, Bize, Sallèles, Kirkdale	Yorkshire.
	b. Sardinia.	
familiaris	*c.* Lunel Vieil.	
other species	*c.* Franconia, Bize, Sallèles	Val' d'Arno, Avaray.
Vulpes vulgaris ?	*b.* Sardinia; *c.* Kirkdale	Perrierburg.
Hyæna spelæa, Goldf.	*c.* Kirkdale, Plymouth, Swansea, Paviland, Muggendorf, Harz, Fouvent, Sundwich, Lunel Vieil, Pondres, Kent's Hole, &c.	Köstritz, Canstadt, Eichstadt, Val' d'Arno, Herzburg, Abbeville, Lawford.
other species, Goldf.	*c.* Franconia, Sundwich, Lunel Vieil	Puy de Dôme, Velay.
Felis spelæa, Goldf.	*c.* Kirkdale, Plymouth, Gailenreuth, Baumann's Hohle, Sundwich, Lunel Vieil	Köstritz, Val' d'Arno, Bielbecks in Yorkshire.
antiqua, Cuv.	*c.* Gailenreuth; *b.* Nice.	
other species		Upper Italy, Puy de Dôme.
Mustela (polecat)	*c.* Lunel Vieil, Gailenreuth.	
(weasel)	*c.* Kirkdale.	
Lutra antiqua, M. de S.	*c.* Lunel Vieil.	
other species ?		Puy de Dôme.
Dasyurus, Hypsiprymnus; Halmaturus; Phascolomys, kanguroo and wombat	*c.* Australia. (Clift.)	
Castor	*c.* Lunel Vieil	Val' d' Arno, Puy de Dôme.
*Trogontherium Cuvierii, (Fisch.)		Taganrok, near the Sea of Azof.
Werneri, Cuv.		Jaroslav.
*Osteopora platycephala (Harlan)		Near the Delaware.
Mus	*c.* Kirkdale, Sallèles; *b.* Gibraltar, Sardinia	Lawford
Arvicola	*c.* Kirkdale, Gailenreuth, Sundwich, Gibraltar, Nice, Cette, Corsica, Sardinia.	
Hystrix		Val' d' Arno.

Name.	In Caverns and Breccia of all Ages.	In Diluvial and Earlier Accumulation
Lepus diluvianus and others.	c. Kirkdale, Franconia, Sundwich b. Cette, Corsica, Nice	Puy de Dôme.
Lagomys corsicanus, Brurdet	d. Sardinia, Gibraltar, Cette, Nice.	
Chloromys		Ditto.
*Megatherium Cuvieri		North and South America.
*Megalonyx Jeffersoni		Ditto.
Dasypus, Bravard		Puy de Dôme.
Elephas primigenius, Blum.	c. Kirkdale, Warksworth, Mendip, Swansea, Muggendorf, Fouvent	Very generally in Europe, Asia, and North America.
meridionalis, Nesti		Upper Italy, Puy de Dôme.
priscus, Gold., resembling the African elephant		Yorkshire, Rhine Valley, Wittenberg, Russia.
several other species, according to Fischer		Russia, Podolia.
*Mastodon maximus, Cuv.		Very general in North America, Norfolk. (Smith.)
angustidens, Cuv.		
andium, Cuv.		Andes. (Humboldt.)
Humboldtii, Cuv.		Chili.
elephantoides, Clift.		Irawadi in the Birman Empire.
latidens, Clift		Ditto.
arvernensis, C. and J.		Puy de Dôme.
Hippopotamus major, Cuv.		In England very generally, Upper Italy, Puy de Dôme.
undetermined	c. Palermo, Australia	Irawadi.
Rhinoceros tichorhinus Cuv.	c. Kirkdale, Warksworth, Plymouth, Swansea, Harz, Sundwich, Fouvent b. Nice.	Siberia, England, Germany, France, Val' d'Arno.
leptorhinus	c. Lunel Vieil	Cussac.
minutus, Cuv.	c. Lunel Vieil, Pondres, Souvignargues.	
elatus, C. and J.		Puy de Dôme.
undetermined		St. Privat d'Allier.
*Elasmotherium Fischeri		Siberia.
Equus, perhaps more than one species	c. Bize, Sallèles Argou, Pondres, Lunel Vieil, Fouvent, Kirkdale, Mendip, Clifton, Plymouth, Swansea b. Nice, Antibes, Gibraltar, Dalmatia, Arragon	Köstritz, Brunswick, Canstadt, Val' d'Arno, Oxford, Essex, Yorkshire, (frequent,) Lawford, &c.
Sus	c. Mendip, Bize, Franconia	Oxford, Val' d'Arno.
other species	c. Sundwich	Puy de Dôme.
*Chæropotamus	b. Villefranche-Lauraguais	Irawadi.
*Mericotherium Sibericum		Siberia.
Cervus megaceros, Hart.	c. Kent's Hole	Very general in lacustrine deposits, probably less ancient than the diluvial deposits, England, France, Ireland.
tarandus priscus	Breugue	Europe.
tarandus		Köstritz.
dama giganteus		Abbeville.
poliguacus		Cussac,
elaphus	In English caverns generally	Frequent in England.
Reboullii, Christol	c. Bize, Sallèles.	
several others	c. Ditto, ditto b. Gibraltar, Cette, Nice, Antibes, Pisa.	Cussac, Puy de Dôme.
Antilope Christollii, M. de S.	c. Bize, Sallèles.	
other species	b. Nice, Arragon	Irawadi, Köstritz.
Ovis	b. Villefranche-Lauraguais.	
Bos primigenius, Bojanus	c. Sallèles, Bize, Lunel Vieil, Argou, Pondres, Souvignargues.	
priscus, Boj.	c. Bize, Souvignargues, Lunel Vieil, Pondres, Argou, Sallèles	Siberia, North America? Yorkshire, and various parts of Europe.
bombifrons, Harl.		Bigbone Lick, &c.
trochocerus, Von Meyer.		Upper Italy.
Pallasii, Dekay		Siberia, New Madrid.
Velaunus		Cussac.
undetermined	Kirkdale, Mendip, Plymouth, &c.	In various parts of England.

We have not ventured to admit into the preceding list, the numerous remains found in the irony sands of Eppelsheim, which are stated to be related to the tertiary limestones of that vicinity, in which also (see Meyer's *Palæologica*) bones of rhinoceros, &c. occur. These remains consist of species of gulo, felis, (not those of the caverns,) several small rodentia, cricetus vulgaris? moschus antiquus, 5 species of cervus, (not those of the diluvium,) rhinoceros Schleiermacheri, (Kaup,) mastodon angustidens, m. arvernensis, 3 species of equus, tapirus priscus, lophiodon Goldfussii, sus antiquus, s. palæocherus, dinotherium giganteum, d. bavaricum, manis gigantea

It may be remarked that in the valley of Rhine, and in some other parts of the Continent of Europe, where local tertiary seas have left agitated deposits along their shores, and in the line of their currents, it requires extreme caution to apply with propriety the term diluvial. By an appeal to the organic exuviæ, where these are sufficiently plentiful, it may often be possible to resolve the doubt, especially where remains of the pachydermata are numerous. Thus elephants, hippopotami, rhinoceros tichorhinus, and certain bovine and cervine remains on the one hand, and, on the other palæotheria, lophiodonta, &c. offer strong contrasts. But this test cannot always be applied, and it then becomes difficult to rely on

the minute distinctions which probably almost always exist between the tertiary and diluvial species of the same genus. In this research much yet remains to be effected. Cases like those of Eppelsheim and Georgesgemund become in this point of view exceedingly important; for, by a comparison of many such instances, the series of zoological changes on the land, between the beginning of the tertiary and the end of the diluvial periods, may perhaps be eventually determined. At present we can only perceive that in general the palæotherian inhabitants of Europe had mostly ceased to exist in these limited districts before the elephantoidal races had spread themselves so widely over the Northern zones; and can clearly show that the proportion of species belonging to extinct genera in the undoubted tertiary deposits, was at least half, while in the undoubted diluvial deposits and caverns of the same date, it was about one-fifth. The remarkable extinct genus mastodon is common to the tertiary and diluvial periods, and there seems good reason to think that in some of the localities in North America, remains of these animals lie in postdiluvial lakes, like those which contain in Ireland and Yorkshire the bones of the cervus megaceros. Some remarks bearing on the general question of the determination of the Geological epochs of marine and littoral deposits, by comparison of their quadrupedal remains, will be found under the head of the tertiary strata.

Deposits of the Modern Era.—Modern Causes in Action.

Relation of terraqueous agencies in ancient and modern eras.

Having now concluded our descriptions of the strata and aqueous products recognised in the crust of the Globe, and also traced the effects of subsequent extraordinary inundations upon the surface, arising from local changes of level or general internal convulsions, it remains to be seen whether the causes now in action in the modern economy of Nature are of the same *kind* as those which were formerly concerned in producing the arrangements and disarrangements observed in the crust of the Globe.

This is the true cardinal point of theory. According as the one or the other conclusion on this point be adopted, we may attempt to explain the ancient phenomena by modern laws of Nature, and thus connect the present and the past, the extinct and the existing history of our Planet into one system of progressive change, according to the school of Hutton, Playfair, and Lyell; or suppose that in the chaotic infancy of our Planet, laws peculiar to that period prevailed, and properties of matter were unfolded then which never show themselves at present; and that the ancient rocks and organic bodies belong to a wholly distinct set of causes, were the produce of a peculiar creative impulse, no longer permitted to operate on the finished and man-inhabited Planet. The Wernerian cosmogony bears very much this aspect.

But though, put this in direct opposition, the rival hypotheses appear to have no point of union, we find, in fact, that between the opinion of Hutton, who considers Creative Nature to be perpetually in progress,—the same to-day, yesterday, and for ever—and the dogma of Werner, that the World was made by a certain settled sequence of events, to which nothing similar now happens, every variety of theory is adopted and defended We may, however, with rigid accuracy and much convenience, rank them in three classes.

1. The favourers of Hutton's and Lyell's views, who maintain that the causes now in action to change the level and alter the relations of the masses of matter near the crust of our Globe, are those which have ever been in action, identical in kind, and equal in degree, in all times past, and which may be expected to continue the same, in kind and degree, through the future.

Views of the English School on this subject.

2. The general School of English Geologists, who have always maintained, and laboured to prove, that the causes operating on the surface and in the interior of the Earth have remained through all times past unchanged in kind, and are still operating with the same tendencies as they always did, but on smaller areas, and with less effect. This view of the subject has a double aspect. English Geologists have generally believed that as volcanoes were supposed to become languid through want of fuel, the *circumstances* under which the modern operations of water and fire are manifested in the general economy of Nature, approach more nearly to a state of equilibrium or saturation, and therefore afford no opportunity for the same extraordinary display of energy as in ancient times; but since the relative periods of the great convulsions which have elevated chains of mountains, and given new boundaries to the ocean have been investigated upon sound principles, the mind has become gradually familiarized to another notion, and habituated to contemplate long periods of ordinary and regular action of natural causes, interrupted by transient local or general convulsions. According to this modification of the hypothesis, the present is a period of ordinary and regular action, succeeding upon an epoch of violent disturbance.

3. The old notion of despairing speculators in cosmogony, who found it easier to cut the Gordian knot, by flatly denying the analogy of modern and ancient operations, and either referring the whole beautiful order of the ancient works of Nature which they could not comprehend, to a momentary fiat of Deity, or to the rude and prolonged confusion of elements in chaos.

This is the only notice we shall take of that mere dream of indolence and deficient observation; for we have already proved that the stratified rocks are certainly analogous in all points to the products of modern waters, and that the unstratified rocks clearly prove their special origin from fire.

As in our accounts of the construction of the Earth' crust we have resolved to separate the results of the an cient operations of fire and water, so in our views of the modern effects of these agents, the same plan will be followed; and, without stopping at every point to settle the precise amount of inference due to every datum, we shall present a connected view of the continual effects o the atmosphere, rains, springs, rivers, and the sea, on the surface of the Globe, before proceeding to the changes occasioned by more occasional eruptions of igneous agents from below, volcanoes and earthquakes, and other connected phenomena. Some general inferences, suited to the present state of the Science, may occasionally be ventured, and perhaps many years must pass before any one acquainted with the peculiar temptations to insecure hypothesis which sciences of observation hold out, will venture to dignify his imperfect generalizations with the delusive title of a Theory of the Earth.

Wasting Effects of the Atmosphere.

The gradual wasting of the surface of the higher parts of the Earth is an important element in Geological theory, and it is scarcely to be supposed that any Geologist can be

Geology. Ch. II. so entirely engrossed with the contemplation of the ancient operations of water in producing the stratified crust of our Planet, as to neglect the consideration of the analogous effects which are in progress at the present time. The following examples of the varied effects of atmospheric influences, in modifying the surface of the erections of man and the works of Nature, are derived from the writer's own observations, and it is to be supposed that they form but a small part of the current information on the subject.

The wasting effects of the atmosphere are those initial or preparatory processes by which earthy materials are provided for rivers and the sea to transport and deposit in new situations.

These processes, as far as they depend on the atmosphere, are chemical when the atomic composition and the properties of the parts are changed, mechanical when their state of aggregation is altered; and this may happen by general humidity, variations of moisture, variations of temperature, or precipitations of rain.

It is not, however, always possible to distinguish accurately the effects of these several causes. Many natural agencies are often concerned in one operation, and the general result is the sum or the difference of their effects. The chemical effects of the atmosphere are evident in buildings and on the surface of certain rocks. The same process which slowly reconverts the mortar of walls into carbonate of lime, frequently causes the pulverization and bursting of the bricks, in consequence of the expansion of the small masses of lime which they contain.

The surface of bricks is often covered with a saline efflorescence, which is generally nitrate of lime, but sometimes muriate of soda. The surface of the yellow limestone near Doncaster is sometimes covered with a nitrous efflorescence, and so is the calcareo-magnesian mortar made from it.

Waste of Felspathic rocks. The exterior of most uncrystalline rocks and buildings seems to be slowly eaten away by the moisture and carbonic acid of the air; but the influence of this destructive agent is most remarkable among the felspathic rocks, whether like granite they are originally crystalline, or like millstone grit composed of fragmented masses. The felspathic portion of the hypersthene rocks of Carrock Fell is so wasted that the crystals of hypersthene and magnetic iron are projected from the surface considerably. Some greenstone dykes are thus entirely decomposed to great depths from the surface, and whole rocks of granite, secretly rotten, wait only for an earthquake, or a water-spout, to be entirely reduced to fragments. Those who have seen the crumbled granite of Muncaster Fell, or Castle Abhol in Arran, surrounded by heaps of its disintegrated ingredients, must have been struck by the importance of this phenomenon in reasonings concerning the origin of many stratified rocks.

Both carbonic acid and oxygen act very decidedly upon the metallic, and particularly the ferruginous ingredients of rocks, and thus swell and burst them to pieces. Sometimes, however, this very cause seems to harden and bind together the rock, and to render it more durable, and in general, there is no certain test of the durability of any stone but experience under the same circumstances. The Bath stone, so permanent amongst its native hills, perishes in the salt air of Norfolk, and few calcareous freestones of any kind will long resist the carbonaceous atmosphere of London.

It is worthy of remark, that sculptured stones buried under ground are perfectly and even wonderfully preserved, while their fellows left exposed to the sky have been almost crumbled to dust. A fine example of this was noticed in the course of the excavations for the Yorkshire Museum, by which the statues which once stood between the arches of the nave of St. Mary's Abbey were discovered, some with blue others with red drapery, one with gilded hair, all retaining the most delicate chisel marks. A few yards from them, at the West end of the Church which they once adorned, the atmospheric influences have nearly obliterated a beautifully sculptured wreath of leaves round the doorway, so that Antiquaries have doubted whether they were meant to represent the vine or the ivy. Preserving power of the ground.

Waste from humidity, Frequently, in looking at buildings composed of porous materials, like the Portland stone, or a grit freestone, we observe the parts which are overhung by a ledge, and thus kept in a state of continual shade and dampness, to be more rapidly consumed than the projections; but the parts which hasten soonest to decay are those near the ground. The same rules are exemplified in many remarkable rocks, as for instance in the quartzose conglomerates of the old red sandstone of Monmouthshire, and the millstone grit of Brimham Crags in Yorkshire. The "Buckstone" near Monmouth is a huge rock inversely conical, expanded above into a large area, but contracted below by continual waste to a narrow base of attachment. This process, a little further continued, might convert the buckstone, as probably some of the stones of Brimham have been converted, into a "rocking stone."

from changes of heat and moisture; In Northern zones the variations of heat and moisture are greatest on the South and West fronts of buildings, and in consequence those fronts to our Cathedrals decay most rapidly. This is remarkably the case with the grand Cathedral of York built of magnesian limestone, which is in many places quite consumed on these fronts, but comparatively uninjured on the Northern face.

The weathering of the surfaces of buildings by the fluctuations of heat and moisture is partly dependent on the structure and composition of the stone. The flagstone of Yorkshire is in many houses at Bradford gradually decayed grain by grain, so that the surfaces of the stone, continually renewed, and never permitting the growth of lichens, appear always neat and clean. The magnesian limestone of the same County, often traversed by veins of calcareous spar, presents frequently a cellular or honeycomb appearance, in consequence of the projection of these veins above the excavated limestone; but the coarse shelly beds of the Northamptonshire oolites, and the irregularly laminated millstone grit, are decomposed in lines corresponding to the inequalities in the composition of the stone.

In these cases the stone appears to undergo gradual and continual waste; but sometimes the whole surface exfoliates. Basalt very frequently suffers this kind of waste, granite not seldom, and it has been supposed in these instances, that the atmospheric action merely discloses the latent concretionary structure of the rocks.

The following examples require a different explanation. The bridge over the Wear beneath the Western towers of Durham Cathedral built (about 40 years ago?) of a sandstone associated with coal, is ornamented with a balustrade, and the little pillars are worked with various swellings and mouldings. In crossing this bridge many years since, the writer struck one of the balusters with his hammer, and being much

surprised with the hollow noise which ensued, stopped to ascertain the cause. It was found, in many instances, that a thin, external coat of stone parallel to the mouldings was entirely separated from the internal nucleus, and ready to scale off upon the slightest blow. The Western front of the ancient and beautiful little Church of Skelton, near York, built of magnesian limestone, shows the same kind of decay in a direction across the bed of the stone. The Yorkshire flagstone is occasionally used, to make curb stones of two feet in height, the laminæ being placed vertically, and the block worked above to a semi-ellipsoidal figure. Even these laminated stones frequently exfoliate parallel to the tooled surface. The ramparts of Zurich are built of sandstone, belonging to the tertiary system, (molasse,) and the stones are cut with a boss along the middle and a depressed border. Desquamation happens parallel to the artificial surface.

Since, in these various instances, desquamations are found to occur parallel to the surface, without reference to the internal lamination of the stone, the mere circumstance of exfoliation seems insufficient to demonstrate the originally concretionary structure of basalt and granite. It is, nevertheless, very probable on other grounds, that basaltic pillars, if permitted to assume their natural shapes, without pressing one against another, would resemble a number of superimposed spheroids.

All the cases of desquamation seem to arise from an alteration of the degree of coherence of the stone, whereby the external crust is made to expand and contract differently from the internal parts, and, in consequence, is soon separated from them. The surface of stones long exposed to the weather is frequently much indurated, while the inner parts remain soft. (This is the case in the outer circle of Stonehenge. Mr. W. Smith.)

from frost.

Frost is likewise an important agent in reducing to smaller masses the materials of the Earth. Some stone, if brought to the surface in Winter full of its "quarry water," will break in pieces directly. Advantage is taken of this circumstance by the slate-workers of Stonesfield and Collyweston, who quarry their stone in the Winter, taking care to shield it from the Sun and the wind till the frost has acted upon it, with the aid of affused water, if necessary, which, by disclosing the natural fissility of the stone, permit the blocks to be cleft into thin, sound, roofing slate. Landslips in mountainous regions are, probably, much accelerated by the power of frosts. In ascending the Righi from Weggis, on the Lake of Lucern, we are much struck by the extraordinary length and continuity of the joints of the nägelflue. It is from these natural partings that the landslips fall, when repeated rains, snows, and frosts have worn or burst them open, and the water passing down them undermines the foundation of the cliff. Thus huge blocks, liberated from their attachments, roll down the steep descent, or half the summit of a mountain slides upon its argillaceous bed. Vast portions have thus slipped from the Righi towards the Isthmus which divides the Lakes of Zug and Lucern, and others are preparing to follow. The fissure is already opened parallel to the edge of the precipice, and pervious below, so that a stone thrown in at the top, is said to fly bounding out at the base.

Effects of rain

We come now to the effects of rain, and without dwelling on the general degradation of the softer surfaces of the Earth caused by this agent, we shall proceed to show, that within the historic era hard and durable stones have been greatly furrowed by the rain, and that in more ancient periods, the precipitations from above have carved themselves channels of various kinds, and sometimes occasioned real though miniature valleys of great length and continuity.

on monumental stones, &c.;

Many Druidical monuments in the North of England are constructed of coarse millstone grit, a rock admirably suited for yielding those enormous blocks preferred by the ancient Architects. Three huge Druidical stones, now standing near Boroughbridge, called the "*Devil's Arrows*," present us with a most instructive lesson on the ultimate fate of all human erections exposed to the ravages of time.

The rain, beating for 2000 years upon these venerable pillars, has cleft their tops, and ploughed deep furrows down their sides. The grooves are deepest at the top, and become wider and less distinct towards the bottom; they cross indifferently the false-bedded layers of pebbles, and go directly downwards. One of the stones leans remarkably and threatens to fall, but an examination of the furrows shows the inclination to be of most ancient date, for they descend much further down the pillar on the upper inclined face than on the under.

Similar effects of rains are visible to a greater extent on the bold crags, like Almias cliff and Brimham rocks, which crown the summits of so many hills of North-Western Yorkshire, from some of which the Devil's Arrows were obtained.

In the valleys of Swisserland (Sarnen) blocks of limestone, which have fallen from the mountain sides, have been furrowed in the same way since their descent.

on rocky cliffs and floors.

The carboniferous limestone of England has been little employed in building, except partially in old castles, where it seems durable, and they who know the magnificent ranges of scars which begird the hills of Derbyshire and Westmoreland, will acknowledge that few rocks seem more likely to endure the rage of the elements. But yet close inspection of these giant cliffs will prove that time has been busy there. The dry and bleached aspect, and the smoothed angles, show plainly the wasted surface. Those who have stood on Doward Hill, near Monmouth, to contemplate the rain-furrowed white limestone there, will not need another example. In the North of England analogous and more remarkable instances present themselves in the wide limestone base of Ingleborough, and in Hutton roof crags near Kirby Lonsdale.

The vast limestone floor which supports the cone of Ingleborough is marked in all directions by natural fissures, and divided into compartments like a map.

If one of these compartments be examined in the Western part of the mountain, its surface will be found scooped into little hollows which unite into a common channel, and terminate by indenting the edges and furrowing the sides of the fissure. They are, in truth, valleys in miniature, separately produced by the drainage, so to speak, of the several blocks.

The mere decomposing effect of the atmosphere produced on the edges of the stones a different effect, by wearing away the softer laminæ, but the smooth surface of the miniature valleys, their regular descent, winding course, and union into a common channel, show that they were fashioned by the repeated operation of descending rain.

This scar is nearly level, but in Hutton roof crags we

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have an opportunity of tracing the rain channels over an immense surface of bare limestone rocks lying nearly level on the hill top, but sloping rapidly down the sides to the East and South. On the level top of the hill the stones are variously worn in hollows and grooves irregularly united and running in different directions according to little variations of the ground; but on the steep East and South slopes the channels are extended into long furrows, which, uniting at acute angles, enlarge, widen, and descend the hill side, in lines following exactly the declination of the rocks, and stopped only by the few and distant fissures beyond which other systems of concurrent grooves begin.

Rain channels like miniature valleys.

It is impossible by drawings, or descriptions, to convey such an idea of the appearances of the Hutton roof crags, as to awaken in others the deep impressions which are fixed for ever in the mind of the observer. The astonishing resemblance which these little rain channels present to the great system of valleys which undulate the stratified rocks, seizes upon the imagination, and we re-examine all our notions of the origin of these great undulations. The fissures in the limestone rocks which stop and swallow up the gathered streams, are analogous to those longitudinal valleys beneath the escarpments of the oolites, and the chalk by which the rivers are turned at right angles to their earlier course, while the lower edge of the fissure corresponds to the escarpment itself, with its new system of denudations.

To see these rain and time-ploughed furrows winding in uncertain directions over the horizontal limestones on the hill top, like a slow river in a level plain, but running a straight downward course on the slopes, like a stream descending from its parent mountains, is enough to impress on every beholder a secure conviction that the excavation of valleys must be explained upon similar principles; that, as the feeble currents of descending rain, aided by long time, have been sufficient to plough their little courses, so the greater action of existing streams has been sufficient to work out their actual channels, though the excavation of the broad valleys in which they run, may have been accomplished by more violent and voluminous waters, flowing in directions predetermined by ancient subterranean movements.

Effects of inundations.

It is probable that the slow but incessant action of rain, beating perpetually on the hard and the soft surface of the Earth, and removing grain by grain the materials loosened by the expansive agency of frost, moisture, and chemical changes, may be, in a given long series of years, more important in its effects than the violent water-spout, or the ravaging inundation of a bursting lake. Yet the effects of water-spouts are tremendous in Countries composed of easily destructible or unequally indurated materials. A water-spout which fell on the mass above Kettlewell in Yorkshire, committed the most terrible ravages in the narrow valley of the Wharfe, near Kettlewell and Starbottom. On the sides of the mountains in Cumberland, traces of these visitations seem utterly ineffaceable; and the memory of the sudden bursting of the Peat Bog above Keighley, will long be preserved in the valley of the Aire. The floods which rushed simultaneously from the Cairn Gorum and other mountains, in August 1829, over 5000 square miles of Aberdeenshire and other Counties, were of prodigious fury, removing hundreds of tons of large stones, whole acres of woodland, and almost hills of earth. The desolating effects of the bursting of the ice-dam which had formed the temporary Lake of Bagnes, are matters of history. The moving mass of water, mud, and monstrous rocks, which swept with violence down the valley of the Dranse, carried away forests, houses, bridges, cattle, and men. In six hours and a half it passed through an unequal and irregular course of forty-five miles, till its waves were lost in the Lake of Geneva.

Glaciers are likewise to be enumerated among the powerful agents by which the higher lands are wasted, and materials provided for the raising of the lower. As the Summer heat melts every year the lower portions of these long winding rivers of ice, and the heated ground thaws, and the gathering water dissolves their foundation, the whole mighty mass of snowy ice slides downwards on its failing bed, ploughs up the stones, breaks up the rocks, and adding their spoils to the accumulations of the avalanches, throws to the sides huge banks of rubbish, provincially called *moraine*. The foot of the glacier is thus surrounded by an immense hill of loose materials which gradually find their way into the stream that issues beneath.

Descending Streams and Rivers.

The wasting effects of the atmosphere, noticed in the preceding section, are sensible in all regions, and therefore in every Country some materials are provided for the streams to transport. But the proportion of matter thus prepared in mountainous Countries is so vastly greater than elsewhere, that in general the less conspicuous effects of the same causes in lower regions are overlooked. The common notion respecting the action of alpine streams appears to be, that *these* are the principal agents of destruction upon the faces of the mountains, and it is to them that the actual waste of the surface is attributed. But though these streams are indeed active agents of excavation, their principal influence is of quite another kind, and it is chiefly by the *disposition* of the materials brought into them by rains, avalanches, and water-spouts, that they effect such important changes.

Erosive or excavating action of streams.

In considering the action of streams and rivers, we must distinguish between their powers of eroding or *excavating*, and of *transporting* solid matter.

The former is occupied on the channel and floodway, and its effects have relation to the *consolidation* of the matter traversed, and to the rapidity and volume of the moving water. About their sources, and for a long part of their early course, streams deepen continually their channels, and wear away their barriers of rock: but in their broad expansions near the sea, this power of excavation wholly ceases, as a general law, and is only evinced in particular cases, as when great bands are cut off or banks are undermined.

We have abundance of examples in all our mountain regions of the actual excavation of their channels by the rivulets and rivers. In the district of Aldstone Moor, the South Tyne runs to the North from the side of Crossfell, for some miles along a slope of shale, over the Tyne bottom limestone. In this shale, which is itself excavated into a broad valley, the river has evidently cut its own narrow yet sufficient channel; and no contrast can be more striking than that here afforded by the mighty valley of Tynedale, 1500 or 2000 feet below its bordering mountains, and the little channel holding the waters of the River Tyne. Every river in this manner works out its own channel in elevated regions,

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and in lower ground the soft clays and sands yield a passage to the feebler currents. In the level regions, along the rivers of Yorkshire and Lincolnshire, the channels have been many times changed, even by those sluggish streams, and still more in the deltas of the Rhine, the Nile, and the Mississippi; and among the Alps, this fluctuation of the river-courses is excessively irregular. No doubt, then, can remain of the fact that rivers and running waters excavate and alter their channels.

Mr. Lyell has given a remarkable case of the *recent* excavation in a bed of modern lava of a channel from 50 to several hundred feet wide, and 40 to 50 feet deep, by the River Simeto, flowing from Etna. Mr. Scrope has also shown similar phenomena to have happened in the volcanic region of Auvergne. In these cases the action of the river has probably been excited by the flowing of a current of lava across its course, so as to dam up the waters, and give them something of the force of a cataract.

Waterfalls, &c.

The waterfalls and cataracts upon the line of a stream afford some curious points of study. It is especially in these cases that the increase of excavating power, derived by a river from the solid matter which it transports, is most sensible.

A cataract is formed upon the River Eden, in Westmoreland, near Kirkby Stephen, by some remarkable beds of calcareous red sandstone conglomerate, and the pebbles which the river brings down, here contribute with the whirlings of the water to excavate many deep perpendicular pits, similar on a small scale to swallow holes on the mountain limestone ranges, or those romantic cavities on the Caldew in Cumberland. Below many waterfalls in Wales and Scotland, the same effect is produced.

But the most characteristic effect of a cascade, is that ceaseless undermining of its base and sides, and consequent rupture of the spout or edge of the fall, which causes by slow degrees the cascade to retire further and further up the mountain side, and produces those awful and still deepening portals of impending rocks, which so much aggrandize the sublimity of a noble *waterforce*.

This effect may be excellently observed in the carboniferous limestone district of the North of England, where so many beautiful streams leap from the beds of limestone over perishing shales and sandstones, and rising in foam sap and undermine the base of a large semicircular cliff, till at length the solid limestone crown gives way, and the insatiable river renews its destroying attacks. The same thing is seen in many of the Swiss waterfalls, particularly in the manifold falls of the Giessbach.

Mr. Lyell very ingeniously applies the acknowledged fact of the recession of the Falls of Niagara, which appear to have been pushed back several miles, at the rate of 40 or 50 yards in 50 years, to the possible discharge hereafter, through the St. Lawrence, of the waters of Lake Erie. Such a discharge would, of course, occasion a local *deluge*; but the lake is so rapidly filled up by sediment, that it is a question whether it will not become dry ground, before the falls of Niagara shall have been pushed back so far as to be capable of emptying it. The fall of the Rhine at Schaffhausen is a grand exhibition of the erosive power of water, particularly the wearing of the base of the two island pinnacles of limestone, which now stand proudly in the midst of the currents, but will eventually be hurled down the thundering cataracts.

Transporting power of streams.

In considering now *the transporting action of streams*, we may distinguish between such as flow through valleys of uniform declivity without lakes, and such as pass through broad receptacles of water, before arriving at the sea. As examples of the former, we may take many rivers of England; for the latter case, several rivers of England, Wales, and Scotland might be named, but much grander phenomena of the kind are witnessed among the streams which flow down from the snow-crested Alps.

Rivers without lakes.

A certain velocity of current is requisite for the transport of every kind of earthy matter, the finer the matter the less force will move it along. Hence in the lower parts of rivers, where their course relents, as they approach the sea, though they can no longer, as in their youthful energy, remove rocks and transport loads of sediment, their waters are muddy, and their channels and sides receive continual augmentation. Such a river as the Yorkshire Ouse is very instructive. As its branches descend from Shunnor Fell, Cam Fell, and Whernside, they transport daily and hourly from those elevated sites the materials accumulated by atmospheric changes and mechanical attrition, the soil, the stones, the loosened rocks, grain by grain, and piece by piece, move onward with the current, and thus the whole mountain region, by a slow yet not imperceptible progress, is lowered in height, and its wasted spoils swept away for ever. But let us follow this process. Wherever the valley originally presented great inequalities, these are constantly diminishing by the upfilling of the hollows, and at length the originally rugged chasm is changed by *additions* and *upfillings* into the smooth, evenly declining hollow, which, because of that smoothness and uniform declination, is supposed by many to be entirely a valley of denudation. In this process, the lateral action of rains and inundations from the sides of the valley, is a very important auxiliary. Any one who contemplates the valleys of the Jura, near Schaffhausen, and sees them in many cases rugged on the sides, and evidently traced by nature in a fit of convulsion, must be struck by the smooth, even, equally declining *plane* of their bottom, which cuts the rude precipices of the sides, and clearly indicates a subsequent powerful modification of the original harshness of the chasm. Still more abundant is the deposit of sediment as the stream glides into lower ground. There, above its narrow channel, rise the broad meads which, with every fresh inundation, receive a new coat of sediment, and above these swell the real boundaries of the valley, often consisting of water-worn materials, gravel and sand, left there by ancient floods of greater power, flowing at a higher level. As we approach the sea, when the tidal currents meet the freshes, the suspension of motion permits a great part of what sediment still remains to discolour the water to drop on the bed of the river, and its alluvial banks. Thus the streams become choked, their channels sinuous, their beds elevated, and the banks which confine the river, heightened both by Nature and Art, look like the ramparts and terraces of a lofty military road rather than the boundaries of a river giving passage to the drainage of the neighbouring country.

The same process at the mouths of rivers pushes their channel and their banks outwards into a cape or headland, and contributes to extend the whole breadth of the bordering coast, so that by the waste of the uplands the low land is filled up, the river-channels are raised, the coast is extended into the sea, and the sea filled with shoals and sand-banks. Thus the mouths of the Po, the Rhine, the Nile, the Euphrates, the Ganges, and the

Mississippi, have formed for themselves those broad deltas which, within the Historic era, have transformed ancient ports into inland towns, and carried fertile pastures into the area of the sea.

The substances transported by the stream, and deposited along its sides, are of course such as the hills around its sources, and above its channel, furnish; and according to the nature of the country, the almost incessant accumulations of earthy matter which thus take place, may be varied by interposed layers of vegetable reliquiæ. In tropical and warm regions, and in uninclosed Countries, this must be the case to a far greater extent than an acquaintance with European rivers would lead us to expect. The mighty forests of America, untouched by human industry, must annually furnish to the great rivers which intersect them, an immense spoil of trees, which being easily supported by the current, will be carried even to the sea, and either deposited at the river mouth, or drifted away on the waves.

Arrangement of materials.

The arrangement of the materials brought down by the streams is in general regulated by a tendency to the production of a level surface, and thus the original inequalities of a valley are continually lessened. In a high region like the Alps, the rough streams leave in the higher level chiefly a collection of pebbles and sand, and they are left in much local confusion; but still the general effect is a uniformly declining plane, through which the capricious stream finds itself new channels, and thus continually shifts its deposits over the whole, broad, pebbly surface. Such effects may be well seen on the line of the Arve, as it hurries down from the glaciers of Savoy. On the contrary, in the lower and more level expansions of a valley, where the gentler waters transport only fine sediment and vegetable reliquiæ, these materials are arranged in most exact parallelism over a large extent of plane surface, and by counting the laminæ of deposition, some useful notion may be formed of the period occupied in the process. On the borders of streams which are periodically swollen by rain, as in the Tropical regions, or by the melting of snows, as in those which descend from high mountain countries, this mode of computation of the laminæ may even be trusted so far as to determine the number of years employed in producing a given depth of deposit; and even in districts where the rivers swell irregularly at uncertain intervals, there might be an *average rule* for the same purpose deduced. Nor would the accumulation of a short period of time, tried by this test, appear inconsiderable. In a single season, the rivers of Yorkshire, aided by the sea, deposit many inches of rich soil upon the level peat-moors which adjoin their estuary; and at Ferrybridge, at the point where the tide, formerly flowing up the river, neutralized the freshes of that river, many of the modern works of man, as oars of a boat, a coin of England, were found buried under the alluvial sediment, which contained petrified hazel-branches and nuts, bones of the stag, &c.

From what has been said of the action of rivers, it is evident that their effects upon the physical features of a country are more varied and interesting than has been generally perceived by those who have written on the much controverted question of the origin of valleys. The tendency of all descending streams of water is the same, to equalize the surface of the earth, to remove all its ridges and asperities, and to smooth all its gulfs and fissures.

The degree in which they respectively perform this depends *first* on the amount of atmospheric and local influences in wasting the surface of the higher ground, and bringing materials for the rivers to act upon. Hence the rapid waste of high Alpine tracts exposed to fluctuating heat and cold, to storms, avalanches, and glaciers. Hence the streams of sand and pebbles which rush from the gritstone hills of England, and, on the contrary, the almost unsullied purity of the springs which break from the carboniferous limestone.

The *second* circumstance which determines the modifying power of the river is its own volume and velocity, and these are principally dependent on the physical geography of the region. The datum of the volume of water flowing in any valley is principally useful for comparison with the *amount of effects*; the *kind of effect* produced is determined by the *velocity* of the current.

If we conceive that in its first fury a river may have power enough to sweep along even large blocks of stone, but that its velocity gradually diminishes, there will be a certain point, where these large blocks will be left by the enfeebled current, pebbles will roll further, coarse sand will travel beyond, and the finer sediment will be moved on till the languid waters permit their slow and equal deposition. This gradation of deposits is always observed in examining valleys of sufficient length and elevations. The deposits in the upper parts are tumultuous and confused, in the lower regions level and regular.

A *third* circumstance, of still more importance than the others, serves to regulate the action of the river. This is the *form and character* of the valley itself. However produced, there can be no question that the present aspect of almost every valley in the World, is smoother and more equalized than it was formerly, since we see evidently and take as a principle, that the characteristic effect of modern causes in action is to reduce continually the inequality which remains. We may, therefore, easily, for each valley, restore in imagination its ancient condition, remove the sediment from its expanded meadows, and leave, instead of level or gently sloping planes that wind smoothly round the hills, and ascend far up toward the sources of the stream, deep chasms between cliffs rent asunder by convulsion, and ridges of rock confusedly crossing the gulfs of the strata. That such has been the origin of many valleys is perfectly evident. That these may have been partly cleared, and others wholly occasioned by violent floods, sweeping over and denudating the land during its elevation from the sea, or by some violent catastrophe at a subsequent period, is also very probable, or rather may be considered as proved. But without entering on these questions, we may content ourselves with the *datum* that the fundamental features of valleys are not the result of the excavating action of their streams, but that valleys have been in part filled up by the accumulations brought by their own rivers, and that their present smoothness and uniformity is really the result of the modifying powers of the atmosphere, local influences and the river, exerted through long time upon a ruder channel, left by more violent and transitory agents.

Rivers with lakes.

Let us now see what peculiarities in the effects of rivers are occasioned by the circumstance of their traversing quiet lakes. Two things are here to be attended to. First, the lake causes, according to its extent, a more complete deposition of the sediment brought by the rivers than is occasioned by the most level dry area of a valley; secondly, the materials dropped in

the lake are regulated by somewhat different laws from those which direct their accumulation on the common surface.

When a river charged with sediment expands into the waters of a lake, its motion, communicated to that large area in directions radiating from the place of entry, relents, and is almost lost, and the sediment which it brought is gradually and, at last, wholly deposited in the lake, whose transparency it disturbs, and the purified stream issues from the lower extremity without a single taint of its stormy origin, *unless it be the colour* of the mountain-peat, or some other substance held in chemical solution. Like the lake from which it escapes, or the ocean far from shore, it generally assumes the purest ethereal hue, its native tint of green or blue, but soon in its onward course it again becomes turbid with sediment. Every lake in Swisserland exhibits these pleasing effects upon the rivers, which commonly enter in turbid violence, and issue of a lovely transparent green, but the Rhone is pre-eminently blue. These lakes are filling and contracting at their upper ends with the sediment which they filter from the rivers, and the process, though historically slow, is monumentally impressive, since we perceive large tracts of level meadows cultivated, covered with trees, and adorned by ancient and modern towns, where formerly flowed the deep waters of the lake.

All this *new land* was formed from the spoils and waste of the upper Countries drained by the river, and it is an exact measure of the whole effect of the atmospheric and local influences in weathering the face of the hills, and of the rivers in transporting away the materials thus prepared for them *from the earliest period when the streams began to flow* down the actual valley.

Arrangement of materials.

The second thing to be attended to in considering the effects of lakes on the line of rivers, is the arrangement of the materials which they receive. This is a subject in which Mr. Yates's observations (*Edinburgh Journal*, 1831) will be found useful. It is known to practical men that loose earth will remain at rest if it be placed at an angle, not exceeding 45° with the horizon, and when loose, earthy materials are poured from a height, they usually arrange themselves in a conical heap, whose sides make nearly this angle with the horizon. On the slopes of mountains liable to avalanches or rapid waste, the loose débris is usually found in a plane declining at about this angle. When streams falling over an edge, pour with their waters a quantity of earthy matter, the conical heap so produced is very much more obtuse than when the materials fall dry, and the larger the proportion of water that comes down, and the more forcibly it descends, the flatter is the slope of the cone. This will easily be understood upon the principle that by partial suspension in water each particle is influenced by the tendency of that fluid to become level.

It is easy to understand from this that the form in which coarse sediment will be deposited by rivers entering a lake, must be in a very obtuse cone radiating round the point of entrance. As the heap of sediment is advanced into the lake by continual additions, its outline remains circular, with a larger radius, and its section will be nearly level toward the land, but sloping more and more rapidly toward the interior of the lake. Were the particles to be arranged in obedience to the double forces of horizontal movement with the river, and of perpendicular descent from gravitation, the curve of the edge would be parabolic, and the surface left upon the sediment toward the land nearly level.

But the earthy matter being unable to support itself at more than a certain angle of elevation, the lower part of the curve will become less steep, and be reduced to a straight line. Mr. Yates's observations on the Swiss lakes led him to assign to the sediment left therein an outline of this kind.

It is obvious that in these cases the sloping layers nearest the entrance of the stream are of older date than those further advanced into the lake. It is an interesting subject of inquiry to learn whether, as is most probable, the particles of the sediment which differ in bulk and specific gravity, are arranged according to those qualities so as to constitute horizontal strata, of finer and coarser matter, &c.; and whether, this being the case, the sloping lines of deposition, &c. are visible or obliterated in the section. In this manner the upper ends of lakes are filled with the deposits from the rivers almost to the surface, and the dams of the lower ends of the lakes being worn away by the incessant action of the stream, these deposits become visible above the water, and constitute those smoothly declining, often moist surfaces, which usually confine within their indefinite border the shallow and weedy waters destined in their turn to retreat from the desiccated land. While this process proceeds near the shore with the coarser particles, it is obvious that the finer sediment will be carried further into the lake, and be spread more widely over its general bed.

These remarks apply only to deep lakes, whose waters rest tranquilly on their beds, and are only agitated at the surface. In shallow lakes, which are agitated to the bottom, the materials must necessarily be distributed in planes very nearly horizontal, in consequence of the impressions from the fluctuations of the surface. This is matter of daily observation.

Lacustrine Deposits.

Before we dismiss the subject of lakes, it will be proper to take notice of another process tending also to fill them with new deposits. Many streams which enter lakes carry along, dissolved in their waters, a quantity of carbonate of lime, which may afterwards, by the loss of carbonic acid from the water, fall in calcareous sediment, and constitute beds of marl, or by the slow absorption of mollusca be converted to shells. In the latter case, beds of limnææ, paludinæ, &c. are formed, and as generally the light argillaceous sediment entering such lakes is pretty equally diffused through the waters, the result is a bed of marly clay full of fresh-water shells. This process is daily going on, and in the course of a few years canals and river courses, as well as ditches and ponds, are choked by the abundant accumulation. In this manner, aided by occasional inundations, bringing layers of vegetable matter, or the detritus of the neighbouring country, have many old lakes become entirely filled up, and when cut open for any purpose, present layers of peat, clay, shell, marl, and sand, a faithful image, on a small scale, of those great fresh-water deposits which mark the force and extent of ancient currents on the surface of the Earth.

Deltas.

The delivery of the sediment of rivers into quiet, tideless, land-locked seas is almost perfectly analogous to what happens in a large lake, but according to variation of circumstances, as the river flows into the open ocean, and contends with strong tides and sweeping currents, or disembogues itself into a gulf, enters deep or shallow water, the disposition of its sediment is dif-

ferent. The most remarkable deltas at the mouths of rivers are formed round such as empty themselves into tideless seas, as the Mediterranean, Black Sea, Caspian, Baltic, &c., or into comparatively quiet bays of the ocean, as the Bay of Bengal, the Gulf of Mexico; and the least effects of this nature are occasioned on coasts which are subject to be raked by lateral currents of the sea.

Most of the great rivers which enter the Mediterranean are daily increasing their deposits along the coasts, and spreading a quantity of sediment over the general bed of the sea. The Mediterranean has been proved by a line of soundings on the Skerki shoal from the African to the Sicilian coast, varying unequally from 7 to 91 fathoms, to be divided into two basins. In the Western portion, near Gibraltar, the bottom, consisting of sand and shells, has been reached at 5880 feet, and in the Straits at 4200 feet. Almost under the shore at Nice the depth is 2000 feet; but in the Adriatic, where it receives the sediment of the Po and other rivers, in the upper part, the greatest depth is 22 fathoms. Yet from the abrupt borders of the hill ground within the area of the sedimentary land, it is inferred that the Adriatic must formerly have been a deep gulf.

Nature of the deposits in gulfs, estuaries, &c.

Further from the influence of the rivers the depth increases considerably. Donati, on dredging the bottom of the shallow portion of the Adriatic, found it to consist partly of mud, and partly of calcareous rock, enclosing shells, which are sometimes grouped in families. (Lyell, 237.) The form of these sedimentary deposits must be what in common language is called horizontal, the substance of them fine clay and calcareous matter with shells, and as the ratio of accumulation is nearly uniform, there will be little appearance of strata, unless the calcareous deposits be accomplished at intervals. If by any effort of subterranean forces this bed of the Adriatic should hereafter be elevated, and made dry land, as so many other extensive tracts along the borders of the Mediterranean have been, we should have an argillaceous deposit extremely similar to the London clay, and perhaps identical with the subapennine marls, except by some difference of organic remains, and of such an extent as would appear incredible to those who believe in the almost quiet slumber in modern times of the mechanical and chemical forces which belong to our Globe. The same conclusions might be derived from an examination of the mouths of the Rhone, Volga, Danube, Ganges, Euphrates, &c. which enter the sea under the same favourable circumstances, and transport enormous quantities of fine sediment into comparatively tranquil and now shallow waters. A river like the Missisippi, which hurries an enormous volume of deep waters, and preserves its velocity to the edge of the sea, discharges likewise a prodigious quantity of matter, which settles round its many mouths into a vast and growing delta. But the kind of matter here deposited, and the mode of its arrangement will be different. Forests matted together by the growth of Ages, with all their foundations, their alligators, and other inhabitants, are swept down by this mighty stream, and either retarded for a time among its winding and variable channels, or hurried into the sea, and there, with quantities of similar matter, agitated, and partially or completely separated into beds of earthy and vegetable matter, the latter varying according to the prevalence of the many rivers which unite in the great stream, and thus the Gulf of Mexico is now filling with deposits, which in no feeble degree emulate our old carboniferous strata. We are informed by Mr. Lyell, whose volumes are full of valuable information on all subjects connected with the modern operations of natural agencies, that a great part of the new deposit at the mouth of the Rhone consists of calcareous and arenaceo-calcareous rock, containing broken shells of existing species; and Captain Smyth ascertained that over the broad, very gently inclined bed of this growing delta, marine shells were occasionally drifted by a South-West wind. In this way alternations of fresh-water and marine shells may be occasioned, in which the marine portions will predominate towards the sea and the fresh-water part be most decided toward the land.

The shorter and more rapid the course of a river, the larger and coarser is the sediment which it may be able to transport. While the Po, relenting in its velocity, leaves its gravel where it joins the Trebia, West of Piacenza, 130 miles from the sea; and the Ganges 180 miles above the commencement of its delta, and 400 miles above the present line of coast; the rough bed of the Yorkshire Tees is pebbly quite down to the sea; and the streams which descend by a short and furious course from the Maritime Alps bear down pebbles into the Mediterranean.

From these instructive examples of pebbly, sandy, argillaceous, and calcareous strata, forming at the same era, in different basins of the sea, and even in different parts of the same basin, enveloping entirely marine, entirely fresh-water, or a mixture of marine and fresh-water deposits, we may turn with advantage and pleasure to the contemplation of the older strata of conglomerate, sandstone, clay, marl, and limestone, and by carefully noting the points of agreement and circumstances of difference, may frame very satisfactory notions of the conditions under which they were deposited respectively. Especially we may be guided in our decision concerning the extent and connection or separation of the several basins of the ancient Ocean, and the relative influence of ancient and modern rivers.

Bars at the mouths of rivers.

Rivers which discharge themselves into the sea, where tides and currents contend with the freshes, may, as the Rhine, be enabled for a certain time to deposit their sediment in a Delta, and to increase this even to a vast degree, in consequence of their entering at a deep emargination of the coast, or amidst shallow sands which impede the action of the tide. But in such a case, the accretion of land must gradually diminish, and at length the movements of the sea must balance the current of the river. In this case a line of sand-banks will be formed varying in position according to the alternate predominance of the contending forces, and the entrance of the river will have a bar. The Rhine, the Thames, and all the Eastern rivers of England are nearly in the same case. The sea, indeed, has again reclaimed from the Rhine, by most destructive floods, the large spaces of the Zuyder Zee and the Bies Boos.

Thus also the growth of the Nilotic Delta, once so rapid, is greatly retarded or almost annihilated by a current of the Mediterranean; and the rivers of Western Africa, as well as the mighty Maranon, no longer extend themselves into the sea, but meet its currents in furious strife, drop the sand at their mouths, and resign their finer sediment to the disposal of the conqueror. The distance to which the Ocean can waft this sediment on its surface along with fresh water is very great. Captain Sabine supposes himself to have crossed the

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discoloured waters of the Maranon 300 miles from its mouth, where it still retained its comparative levity, and kept its place on the surface of the sea.

Thus may the sediments of distant Countries be mixed or alternately deposited far from shore, and even in the deep sea, a fact of great interest to Geology. The distinctness of currents of water which flow down the same river channel, even with a rapid descent, has often been noticed. Thus the Arve and the Rhone flow far without mixing, the Nahe takes one side of the Rhine, and even in the mining districts of England, the discoloured streams from the different valleys can often be distinguished along considerable lengths of the united river.

We shall not further extend our remarks on this subject than by stating a few instances of the actual surface of the Deltas of great rivers. The whole area of the dry Delta of the Po and the Adige, and other rivers which contribute to the effect on the same line of coast, must exceed 2000 square miles, and within the last 2000 years a space of 100 miles in length, and from 2 to 20 miles in breadth, has been added to the land. The area of the Nilotic Delta is about 12,000 miles, and according to Girard the surface of Upper Egypt has been raised by the sediment since the Christian era 6 feet 4 inches; of the Rhone 1500 square miles; of the Quorra 25,000 square miles. (Dr. Fitton, *Geology of Hastings*.)

The Delta of the Ganges, without reckoning that of the Brurampootra, which has now become conterminous, is considerably more than double that of the Nile, and its head commences at a distance of 220 miles in a direct line from the sea. The base of this magnificent Delta is 200 miles in length. (Lyell.)

The fen lands of Lincolnshire, Huntingdonshire, and Cambridgeshire occupy 1000 square miles, and the levels in connection with the Humber 300 or 400.

It has been attempted to deduce the age of our continents for the rate of increase of the Deltas of rivers within the Historic era. Thus the Nile was supposed by Herodotus to have formed Lower Egypt; and he states that if diverted into the Red Sea, it would fill that gulf with its deposits in less than 20,000, or even 10,000 years. Since the time of Herodotus it is supposed that the increase on the Nilotic Delta has been upon an average, one mile and a quarter. The average annual growth of the Delta of the Po, opposite Adria, which was once on the edge of the Adriatic, was, from 1200 to 1600 A. C., 25 metres, and from 1600 to 1800, 70 metres; a very rapid increase of rate, probably connected with the increasing shallowness of the sea. (Lyell, *Principles of Geology*.)

But all inferences from observations of this nature, and similar ones on the shallowing and conversion to land of the upper ends of lakes, can lead only to merely speculative results without the knowledge of a datum very difficult to be obtained, *viz.* the original depth of the sea, at all points over which the river sediment has flowed; for it is not by the *area* of the Delta, but by the *cubic content* of the sediment transported that the time occupied in the process is to be ascertained. How is this to be determined?

The Sea.

As the action of rivers is of two kinds, erosive and transporting, so is that of the sea. In one place its fury excavates the cliffs, and devours a whole country, in another every tide adds sediment to a growing shore, lengthens the fields, and extends the parishes, till what was once a broad bay becomes a fertile marsh, and the town which was once a flourishing port is far removed from the waves, and never visited by commerce. These different effects depend principally upon the circumstances under which the earthy materials are presented to the waters. Cliffs exposed to the sea are either slowly decomposed by its vapours, and crumble piecemeal, or undermined at the base, and so caused to fall in ruinous heaps. Even the hardest rocks that begird the Ocean are more or less wasted away by its never-ceasing attacks, conjoined with the common atmospherical agents. Soft places are scooped into caverns, joints are widened, and blocks loosened, and thus, by little and little, every high coast recedes and yields more or less ground to the insatiable waves. But cliffs composed alternately of softer and harder strata, especially if there be any dislocation, are quickly eaten away, and still more rapid destruction falls annually on the crumbling diluvial clays and loose gravelly cliffs which margin so great an extent of the coast of England. The whole of the English coast may be cited for cases of this important wasting of the cliffs, and in particular the diluvial cliffs of Yorkshire and Norfolk. In the former County it seems to be ascertained, by careful measurements at many points, repeated after intervals of many years, that the annual loss of land on the whole length of Holderness, is not less than 2 yards in breadth annually. The average loss on the coast of Norfolk between Weyburn and Theringham is about 1 yard per annum, on the coast of Thanet 2 or 3 feet. But these same coasts likewise exhibit, on an equally grand scale, the formation of *new land* from the materials thus detached from the old. The materials which fall from the cliffs are sorted by the tide, and according to their bulk and weight are differently disposed of. As in many artificial processes of washing powders the sediment is divided into parts of different fineness by merely shaking it at different distances or depths in the stream of water, so it is in the great currents of the sea. Large stones remain a long time at the foot of the cliff from which they fell, smaller masses yield something to the impetus of the waters, sand and pebbles are drifted along the shore according to the set of the tide, and collected into bays and hollows of the coast, or deposited in a line of moving beach; but the finer clays are transported far away in the waters, and allowed to settle only where these rest in land-locked gulfs, stagnate over weedy marshes, or lose their force in contest with the freshes. The breadth of the sandy beaches thus accumulated is often very great, even many miles of slow and regular descent. The sand-banks which stretch out so far from the low coasts are often regarded as remains of ancient lands overwhelmed by the sea, but in most cases they are probably recent formations, accumulated by the waves from the spoils of other regions. But what is thus left by the sea under some circumstances, may be again reclaimed by it under others. The once fertile district called North Friesland, most probably accumulated by the sea, measuring from nine to eleven geographical miles from North to South, and six to eight from East to West, was in 1240 entirely severed from the continent, and in part overwhelmed. The Island of Northstrand, thus formed, was, towards the end of the XVIth Century only four geographical miles in circumference, but still was richly cultivated and populous. At last, in 1634, in one night, the 11th of October, a flood passed over the whole island, whereby one thousand three hundred houses, with many churches, were lost, fifty thou-

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Wasting of Cliffs.

Extension of Marshland.

sand head of cattle and above six thousand men perished. Three small isles alone remain, and they are still further wasting. (Lyell.) It may often be remarked that substances thrown into the sea are not carried down at once to its depths, but rejected many times to the shore, in the direction of the tidal currents. This happens especially with all light, small, and easily moved bodies; but the case is different with the large blocks of stone, which, continually pressing by their weight downwards, are for the most part gradually withdrawn from the base of the cliff sunk in the beach, and rolled down to the deep.

In this manner, when the circumstances admit of it, the whole coast is in motion, every high cliff wastes away, the low grounds stretch out, the beach widens and again contracts, shifts upwards and downwards, and travels along, and thus amidst the extremes of constant fluctuation and change, new deposits are continually added to the quiet depths of the sea, and to the lowest parts of the land. As far out as the fluctuations of the waves can influence the bottom of the sea, the new deposits, where uninfluenced by currents, must become nearly horizontal; in greater depths it seems reasonable to suppose that the materials will be arranged nearly as in deep lakes; and under the cliffs, the beach being only at intervals exposed to the rush of ascending and descending waves, must have its surface inclined at corresponding angles.

We have no accurate data on which to found an opinion concerning the utmost depth to which the influence of the superficial undulations of water may extend. The influence of the tidal and other *currents* of the sea must extend to a great depth, and tend to equalize into nearly horizontal strata the loose materials collected from the waste of the land.

Coral islands, &c.

These extensive deposits of sand and clay are, however, not the whole of the productions of the sea. The Ocean indeed is but a large lake, and, besides the mechanical effects on its borders, is subject to various chemical changes, and to the unceasing agency of the functions of Organic Beings. Into that vast repository there flow annually great quantities of soluble matter of various kinds, and it is quite conceivable that by the interchange of their elements some chemical deposits may happen. It is also not unreasonable to admit that many exhalations rising from the bed of the sea may cooperate in such effects. But there is one ascertained cause incessantly in operation which probably occasions more extensive and permanent precipitation of carbonate of lime than any other process, the growth of zoophyta, shells, and crustacea. However small may be the quantity of calcareous matter suspended in water, the molluscous and zoophytic animals, which require such matter for their stony supports, are sure to possess themselves of it; and as corals and shells remain when their tenants dissolve away in the water, the bed of the sea is continually receiving important additions from this source alone. Besides these, the cast shells of crustacea, the teeth, and sometimes the skeletons of fishes and cetacea, must contribute no mean quota to the growing stock. It is perhaps yet an undetermined question to what depths in the sea light and the vital influence of the atmosphere can sustain the growth of plants and animals. We may, however, safely believe that the extreme gulfs of the sea are as devoid of organic life as the central solitudes of a sandy desert, while the borders of the one, and the shores of the other, teem with innumerable forms of life.

It was formerly supposed that those immense reefs of coral which divide the waters of the Pacific Ocean, and rear themselves above the waves into associated islands, arose from the deepest parts of the sea, in perpendicular walls. But many observations by Captain Beechey and other navigators, upon the crater form which the coral islands generally assume, and the volcanic rocks upon which they are frequently based, have produced a very general impression that the polypean races do not exist except at moderate depths. Captain Beechey found the coral of Ducies Island to be forming at a depth of one hundred and eighty feet.

The quantity of carbonate of lime thus produced by the coral animals, with the addition of shells, &c. enveloped by them in their progress, is really enormous, and might almost justify those Geologists who think that our stratified limestones are wholly derived from comminuted shells and zoophytes. A great proportion of all the low islands in the South Pacific Ocean is the work of zoophytes, and new islands are daily in progress, and submarine reefs of so great extent that Captain King found a continued line of coral reef 700 miles in length, from the North-East coast of Australia towards New Guinea. It was interrupted only by a few intervals not exceeding in the whole 30 miles in length. These reefs consist in great part of compact limestone, and Mr. Lyell compares them to the ancient calcareous rocks of the basins of Europe and North America.

This comparison, so just as to quantity of material, must not be extended to the structure and arrangement of the several masses. The rocks of carboniferous limestone have indeed derived a large part of their materials from the calcareous secretions of polypean and molluscous animals; but the materials can have been put into their present stratified form only by the ordinary mechanical action of water upon them. A modern coral reef might, by long movement in water, be ground up into something like a limestone bed, but the sharpness of the angles of the ornamented fossils of all the old calcareous strata appears to disclaim such an origin for these rocks. At the same time it is to be observed that the corals and other zoophytic reliquiæ, which abound in some of our limestones, very seldom appear to be in their ordinary places of growth, but rather seem to have been subject to some drifting. The corals may therefore in ancient times have grown in reefs, as at present, and this may perhaps be the reason of their irregular and unequal dispersion in the rocks—a fact particularly remarkable in the coralline oolite.

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CHAPTER III.

DESCRIPTION OF THE ROCKS PRODUCED BY IGNEOUS AGENCY.

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Introduction.

In the preceding Chapter we described the series of aqueous deposits which contribute to form the crust of the Globe, commencing our account with those of the earliest date, and terminating it with the consideration of the most modern.

In the present Chapter a similar order cannot be observed, inasmuch as in the case of the igneous formations which it becomes our next business to consider, we do not possess those criteria, derived from the order of superposition, and the nature of the imbedded fossils, by the aid of which we were enabled to determine in the former instance the question of relative antiquity.

Neither, indeed, are we entitled to take for granted *in limine* the igneous origin of all the rocks which will fall under our review, seeing that some of them have, until very recently, been attributed to causes of quite a different character, and that even at the present day they are regarded by some Geologists as of questionable formation.

It will be more satisfactory, therefore, in the present Chapter, to reverse the order of arrangement adopted in the preceding one; considering in the first place those operations of an igneous description which are going on in the interior of the Earth at the present day, tracing the effects which have arisen from similar causes operating during the historical period, and thus gradually ascending to the consideration of such apparently analogous phenomena, as may seem referable to those same agencies, acting at a still more remote era, and under circumstances in some respects different.

In this manner, we shall be best enabled to pronounce upon the origin of such rocks as deviate too widely from the structure and constitution of the products of igneous action which we see at present forming, to be referred at once and without examination to the same cause, and which, whatever may be their exact date, are at least not seen to be produced by causes now in operation.

Proceeding, then, from the known to the unknown, referring in the first instance all that is possible to existing agencies, and preferring to explain the remainder, by assuming a greater intensity of the same forces, rather than the influence of others of a different kind, we shall consider it our primary object to treat of volcanos at present in action; these being confessedly the most powerful and widely diffused of the igneous agents which are at work.

We shall therefore inquire, what phenomena, observed to take place under present circumstances, may reasonably be attributed to such a cause; and if it should appear, that all the changes of any importance going on on the Earth's surface which remain to be discussed, may without difficulty be referred to its agency, our task will then be greatly simplified, inasmuch as it will be limited to the consideration, in the first place, of existing volcanos and their consequences, and secondly of those which are extinct; after which we shall proceed to inquire into the nature of those granitic rocks and of others, which have protruded themselves, at different, though always at epochs antecedent to the present, through the aqueous deposits which compose the crust of the Globe.

PART I.

ON ROCKS PRODUCED BY IGNEOUS OPERATIONS OF A SIMILAR NATURE TO THOSE NOW TAKING PLACE.

SECTION I.

Description of Volcanic Phenomena in different Parts of the World.

General Notion of Volcanic Action.

If we contemplate a volcano whilst in a state of vigorous action, the phenomena presented to us are at once so peculiar and so impressive, that it would seem unnecessary to be at the trouble of defining that, which the commonest observer could hardly fail to recognise again, in whatever part of the Globe it might fall under his observation.

The evolution of smoke and ignited matter from an orifice in the Earth, generally situated on the summit or flanks of a conical mountain, the ejection of fragments and scoriæ, bearing a near resemblance in their condition and aspect to the slag of an iron foundery, the sudden and copious extrication of elastic fluids, with their natural concomitants, noise and a concussion of the rocks through which they force their way, are circumstances which strikingly impress upon the imagination the paroxysms of volcanic action, and appear to distinguish this from all the other operations of Nature.

Accordingly from the earliest periods the existence of volcanos had excited attention, and their leading phenomena were pretty correctly described. They have supplied a groundwork for the superstitions of the vulgar, and for the speculations of the philosopher, and much of our present knowledge with regard to the character, extent, and date of their operations, may be collected from the incidental notices of them, transmitted to us by the Historians, and even by the Poets of antiquity.

Nevertheless, when we examine the subject more attentively, difficulties occur with respect to the real relation borne by them to several of those phenomena, which from some obvious feature of similarity have been regarded as their offspring.

If, in conformity to the vulgar idea, all *burning* mountains are ranked amongst volcanos, we admit into the same class a variety of incongruous appearances, which possess indeed no one character in common, except that of being accompanied, with what seems at least to be an emission of flame, and which are therefore assignable in all probability to causes of many different kinds. If, on the contrary, none, but such as present this obvious resemblance to existing volcanos, are to be included in our definition, we lose the advantage of considering a series of effects, evidently allied to the subject before us, and perhaps equally illustrative of its real nature.

How different, for example, are the eruptions of Vesu-

vius and Etna, in *kind* as well as in *degree*, from the emanations of gas and aqueous vapour, which proceed at times from the sulphureous soil at Macaluba in Sicily, from the foot of the Apennines near Modena, and still more remarkably, it is said, in Crim Tartary, and in the neighbourhood of the Caspian; or from the emissions of gas now observed at Pietra Mala, between Bologna and Florence, and the spontaneous fire (as it was believed to be) which in ancient times added to the superstitious reverence entertained for the sacred peaks of Parnassus.

On the other hand, if we consider the character of the phenomena exhibited, how intimate is the connection between the eruptions of Vesuvius and the earthquakes or hot springs in its vicinity; and, looking only to the nature and constitution of the mineral products, how impossible is it to draw a line between those which have *evidently* resulted from its eruptions in modern times, and many rocks in the contiguous country, where nothing of a volcanic nature has as yet been noticed as occur-

Phenomena attributable to Volcanic Action.

In order, therefore, to establish a sufficiently broad basis on which to ground any general conclusions with regard to the agency of this cause throughout Nature, it seems necessary to settle in the first place, what phenomena, independently of those more palpable ones which first occur to the imagination, are to be regarded as indicative of volcanic action, exerted under the same circumstances as at present, though, possibly, at a very remote period.

It is clear, that the date of the eruption, which gave rise to these effects, will be immaterial to our present purpose, provided we possess an equal certainty as to its reality: and we shall be entitled to avail ourselves of the evidence to be derived from extinct as well as existing volcanos, just as the traveller, who should endeavour to collect proofs of the existence of iron founderies in an unknown country, might be at liberty to infer their presence, not only in places where they were at the time established, but also wherever such accumulations of slag and scoriæ were found, as could only have arisen from the same formerly in operation.

Phenomena admitted to be Volcanic.

Now the circumstances, which may be held sufficient to substantiate the existence of volcanic operations, of a description similar to those now proceeding, are derived from three sources:

1. Indications of internal commotion; manifested in the ejection of heated stones and scoriæ, the emission of lava currents, and the evolution of aqueous vapour, together with certain gases hereafter to be described.

2. The structure and appearance of the masses taken collectively; namely, the existence of a mountain approaching to a conical form, and composed either wholly, or at least superficially, of strata, possessing what is called a quaquaversal dip, or sloping away in all directions from a common centre, where some vestiges at least remain of a crater-shaped cavity.

3. The condition of the individual rocks themselves; namely, the presence in them in a greater or less degree, of a vitreous aspect and cellular structure, with a corresponding chemical constitution, in which some of the combinations of silica with the alkalies and alkaline earths form the prevailing, or, at least, the most constant ingredients.

Now we have no evidence, that either the mechanical or chemical characters above described have ever resulted from aqueous solution, whilst both the one and the other are familiar to us, as the effects, not only of volcanos, but also of artificial heat.

Without, however, pretending in this stage of the inquiry to assert, that the constitution of the mineral masses above assigned is sufficient in itself to establish the action of heat, we may be justified in concluding, that where it is conjoined with the cellular structure and glassy aspect alluded to, it may fairly be assumed to owe its origin to volcanic operations. In many, indeed, of those of modern date, the cooling appears to have been too rapid, to allow of any crystalline arrangement of the constituents taking place; and in a still larger proportion, though numerous crystals of augite, hornblende, and other minerals, may be disseminated, yet the basis of the rock cannot be identified with any known mineral or mixture of minerals, though apparently made up of augite and felspar in various proportions, and consequently presenting all shades of colour from grey to black. In these cases, the vitreous character, which more or less completely belongs to the rock, is sufficiently conclusive as to its origin, but the mineral composition can only be inferred from analogy, at least by common observers, who want either the patience or adroitness to adopt the mechanical method of examination, by which M. Cordier, it is said, contrives to separate and distinguish minerals too intimately blended to be recognisable by the eye or the lens. Indeed, the very employment of this method presupposes a certain confused crystallization, and is, by M. Cordier's own confession, inapplicable to many volcanic products, which, after having undergone fusion, were placed under circumstances precluding any new arrangement of the particles from taking place. Yet, wherever this is not the case, or what, practically speaking, comes to the same thing, wherever the component minerals are not too much blended together to be determinable, we generally find, that the basis of the rock is of a felspathic nature, rendered porphyritic by the presence of crystals, either of the glassy variety of felspar, or of some mineral of the hornblende or pyroxenic families.

The presence of the two latter, in sufficient quantity to impart their characters to the mass, stamps it as belonging to that class of volcanic products which has been denominated basaltic, and distinguishes it from the more purely felspathic kind, in which such ingredients are only of scanty and partial occurrence.

The latter class of ignigenous products, which consists for the most part of compact felspar, with crystals of glassy felspar imbedded, (owing to the harsh and gritty feel belonging to most of its varieties,) has been denominated trachyte, from the Greek word, (τραχυς, rough;) it has been observed by Von Buch and Humboldt to form, as it were, the basis of many existing volcanos, and even constitutes the material of certain lavas apparently of modern formation.

Amongst extinct volcanos, many entire mountains, and even vast tracts of country appear to be composed of this rock, which, whilst it passes on the one hand into clinkstones and phonolites similar to those occurring in the trap formations, graduates on the other into the species of volcanic products above alluded to, in

proportion as crystals of augite and hornblende begin to be superadded to those of glassy felspar, which are essential to it.

The second class of volcanic products, distinguished by the predominance of these minerals, has been denominated by Mr. Scrope greystone; and as this term has a more English cast than the corresponding one, *tephrine*, which M. Brongniart had imposed upon rocks so constituted, it may be convenient to adopt it.

The greater part of modern lavas, whose constitution can be made out, appear to be composed of this species of rock, which is of course divided into a number of varieties, by the presence of sundry accidental ingredients, such as olivine, mica, titaniferous iron, and the like. In one or other of these classes, all volcanic rocks may probably be arranged which possess any discernible mineral structure; and those, in which fusion and rapid cooling has obliterated all traces of this kind, may nevertheless be referred with some degree of probability to one or the other.

Thus the pearlstones and the white pumices appear, from their chemical composition, as well as their external aspect, to be derived from trachyte; the absence of the materials of augite and hornblende being evinced from their not containing iron; whilst the obsidians and the lithoid lavas generally partake of the character of greystone, the proportion of *oxide* of iron serving to show (even where their mineral structure is undiscernible) that augite has contributed to their formation. The same remark, indeed, applies to the case of *basalts*, properly so called; and the difference of structure which is discernible in passing from the obsidians to the true basalts, between which the different varieties of modern lavas seem to be, as it were, the connecting links, indicates, that they have been all derived from some common matrix, which, after having undergone fusion, had cooled under different circumstances.

The only exception to this, is the larger quantity of alkali present in certain obsidians than in basalts and lavas; a circumstance which may, perhaps, enable us to explain, how it happens that this mineral, which we are disposed to attribute in general to sudden cooling, shall nevertheless be found occasionally to constitute streams of considerable size and thickness, where we might therefore expect lithoidal lava to have been produced.

The rocks above noticed may each of them exist under several different modifications of form and aspect; they may occur, either as loose, detached blocks, ejected, probably, in a solid, or, at least, a semi-fluid state from the crater, or as the constituents of a kind of tuff; fragments of various sizes being imbedded in a sort of loose iron-clay or sand, denominated puzzolana; or, lastly, they may constitute a bed of lava, which once issued in a continuous stream from the interior of the volcano, whilst in a state of vehement activity.

To give to such materials in all the above cases the name of lava, as some Geologists have chosen to do, is obviously incorrect; this term having reference, properly speaking, not to the particular constitution, chemical or mechanical, of the mass, but to the mode of its ejection from the volcano; and being, therefore, improperly applied to rocks which appear to have been projected in detached fragments into the air, and never to have formed part of a current of melted matter.

We likewise coincide with Mr. Scrope in condemning the limitation of the term trachyte to felspathic rocks of a particular age and position, thus excluding those lavas which possess corresponding mineral characters. That rocks agreeing altogether in mechanical structure and aspect with the trachytes of tertiary formations are uncommon amongst the older rocks, may, indeed, be true; but to lay down as a rule that the porphyries of one particular age are alone to have this title, is to prejudge the question, and to proceed on quite a wrong principle in framing our nomenclature.

Division of Volcanic Products according to their relative Ages.

Volcanic products have been distinguished by some Geologists according to their relative antiquity; those which appear to have been ejected antecedently to the period of the excavation of the contiguous valleys being denominated *antediluvial*, and those of subsequent ejection *postdiluvial*. Others have objected to this distinction as involving an hypothesis; since, as we have seen, it is still a question of debate whether valleys of denudation have been produced by short periods of general convulsion, or by the continual operation of rains and torrents, acting with only their present force and violence. Perhaps, however, the terms may still be admitted by Geologists, of whatever school, with the same mental reservation, as that, with which many have been in the habit of employing the corresponding ones, of diluvial deposits, diluvial gravel, and the like. They serve to distinguish the relative antiquity of the rocks so classified, with greater precision than the terms of *ancient* and modern, which it has been proposed to substitute, since they refer to a definite standard, which leaves no doubt in the mind as to the sense in which we *employ the word* antiquity in our Geological language.

Without some such understanding, indeed, the volcanic rocks in Auvergne might be called ancient, with reference to those of the Vivarais, though they are modern when compared with others in their own neighbourhood; whilst in either point of view they must be regarded as postdiluvial, since their relation to the valleys of the country is such, as to prove, that no great changes have taken place in the configuration of the surface, since they were ejected.

Even if it be true, as Mr. Scrope contends, that there are lava currents in some of these volcanic districts, as in Auvergne, which appear to be antecedent to some of the valleys of the country, and posterior to others, there will still be nothing to preclude us from applying the above denomination to cases in which this cause of uncertainty does not exist.

Postdiluvial Volcanic Rocks.

Now the importance of distinguishing the relative ages of volcanic rocks, in the manner above proposed, will be evident from considering, that the two classes commonly differ one from the other in aspect and structure. The postdiluvial volcanic products having, in almost all the cases in which they come under our examination, been ejected in the open air, and, consequently, for reasons which will be afterwards explained, having in general cooled more rapidly, present for the most part a harsher feel and more of a vitreous aspect; whilst from the character of their component masses, even more perhaps than from the shorter period, during which their surfaces have been exposed to atmospheric action, they are but partially covered with soil, and admit, consequently of but a scanty and inferior pasturage.

For the same reason, they consist more commonly of those volcanic products, in which the constituent parts are blended together so as to be undistinguishable, though from their general appearance, and from the character of those portions in which the mineral composition may be discerned, it would appear, that basaltic lava or greystone predominates over the purely trachytic, in those modern volcanos with which we are best acquainted.

Antediluvial Volcanic Rocks.

The antediluvial volcanic rocks, on the contrary, are not only characterised by valleys of precisely the same kind as those which intersect the contiguous country, but likewise, by a greater tendency to crystallization in their constituent parts, by a greater predominance of felspar, by the occurrence of masses sometimes in no way distinguishable from the basalts and greenstones of the trap formations, and still more frequently exhibiting a nearer approach to them, than is observable amongst the products of igneous action at the present day. Though frequently cellular, their cells have not that glazed internal surface which characterises many modern lavas, and are usually more or less completely filled with crystals of carbonate of lime, zeolite, and other minerals, which are not so frequently found amongst postdiluvial lavas.

What variation in the circumstances under which the former were ejected could have given rise to these differences, will form a subject for future inquiry; at present it is only necessary to point them out, as a reason for distinguishing volcanic rocks into two classes according to their relative antiquity, those ages being determined, either by their shaping their course in conformity to the present configuration of the country, or being themselves intersected by the so called valleys of denudation. The opinion which may be entertained with regard to the origin of such valleys, will not materially affect the question as to the propriety of availing ourselves of such a distinction; since the vast difference, between the width and depth of the valleys which in many cases intersect the *older* volcanic rocks, and that of the ravines which evince the action of existing causes upon the *modern*, proves, that if the same agencies, operating with their present intensity, have produced the former, it can only have been after a lapse of ages beyond comparison greater.

In Auvergne, for instance, where the most modern volcanos appear to have been anterior to the Christian Era, the utmost amount of the excavation effected in them by present causes, is to produce a ravine or water-course, in some instances, indeed, as much as from fifty to seventy feet in depth, but still of very inconsiderable breadth; whilst the ancient volcanic rocks are characterised by valleys possessing the easy and gradual slope of those which belong to the older rocks of the country, and like them, often many hundred feet in depth, and perhaps a mile or two in diameter. Another important distinction in the character of volcanic products, depends upon the situation of the point in the Earth's crust on which the eruption breaks out, and in particular upon its occurrence either in the open air or under deep water. We say, deep water, because in shallows no great influence could be expected to be exerted, and the phenomena would therefore resemble those which take place in air. But, between the nature of products arising from the same volcanic action, under the pressure of only one, or of a thousand atmospheres, considerable difference might be anticipated; and hence it becomes proper *in limine* to mark the distinction designating the former class of volcanos as *subaerial*, the latter as *subaqueous*. The characters of these two classes will be considered afterwards; but in the first place we will proceed to give a brief description of the principal foci of volcanic action distributed over the face of the Globe, conceiving, that by so doing, we shall enable our readers to obtain a better notion of the general character of the phenomena themselves, than could be gathered from any more abstract account of them.

We shall, therefore, begin with the vicinity of Naples, not only as supplying us with one of the longest known, and best described instances of volcanic agency that exist, but likewise as exhibiting these phenomena under all their various phases of activity, contrasting the effects produced in earlier periods of the World with those going on at the present.

Vesuvius.

To the East of the Bay of Naples rises the most recent of the volcanos met with in that neighbourhood, and the only one at present in complete activity.

The date of that part of the mountain properly called Vesuvius, or rather of its cone, perhaps does not go further back than the period of the famous eruption of A. D. 79, in which Herculaneum and Pompeii were destroyed; for the ancient writers never speak of the mountain as consisting of two peaks, which they probably would have done if the Monte Somma had stood, as at present, distinct from the cone of Vesuvius.

Other facts might be also mentioned to show, that the old mouth of the volcano occupied the spot now known by the name of the Atrio del Cavallo, but that it was greatly more extensive than that hollow, comprehending likewise the space now covered by the cone, which was thrown up afterwards, in consequence of the renewal of the volcanic action that had been during so many ages suspended. This spacious crater was probably the spot in which, according to Florus and Plutarch, Spartacus and his Gladiators were besieged by the Roman General Clodius Glaber.

We infer from the account given, that the brim of the crater was entire, except in one part, by which the insurgents had entered, and which the enemy kept closely guarded; and the great steepness of its sides is evinced by the scheme which the besieged party were compelled to adopt in order to effect their escape; that, namely, of twisting into ladders the vine twigs that grew upon the top, and descending by means of them to the bottom, where they surprised the Roman Camp. Nor does this seem inconsistent with the account given by the accurate Strabo respecting the structure of Vesuvius in his time; namely, the fertility of its sides, and the barren flat which constituted its summit; this flat being in all probability the spot occupied by Spartacus, broken away on the side fronting Naples, but encompassed elsewhere by steep precipices, the relics of the original brim of its crater.

It appears then, both from the silence of ancient writers, and from the appearance presented by the mountain itself, that a long interval had elapsed since any indications of activity had been observed; and the first symptom of internal agitation given by the volcano was in the year 63 after Christ, when an earthquake

occasioned considerable damage to many of the cities that had been built in its vicinity. But it was not till the year 79, that the first eruption of Vesuvius took place, of which any historical records exist. It overwhelmed the cities of Stabiæ, Pompeii, and Herculaneum, with showers of sand, pumice, and lapilli, and seems to have covered the latter to a still greater depth with a kind of mud eruption similar to those which are produced, not unfrequently, by the volcanos of South America. Such, at least, is the inference that has been drawn from the circumstance, that the former towns are covered only with strata of incoherent materials, little, if at all, affected by water, whilst the latter is buried in a kind of tuff, separated at intervals by strata of white volcanic lapilli. The depth at which Pompeii is overspread does not exceed 14 feet, and that at Stabiæ probably is nearly the same; whilst at Herculaneum the mass of tuff alone above the theatre is not less than 85 feet, over which, it is stated, occur 12 or 14 palms of common soil, and this is covered again by a true lava, probably of much more recent date. That the tufa was at first soft, is evident, from the impression of a woman's breast, and other parts of the figure being found in this volcanic deposit, possessing, it is said, a sharpness, equal to that of a cast in Paris plaster.

The difference between the substance which overwhelmed these cities, is evinced by the state of the papyri discovered in the houses, that have been since freed from the load of matter which had encumbered them. In those met with at Pompeii and Stabiæ, which are covered by a more uncemented congeries of sand and stones, decomposition has proceeded so far, that their contents are illegible, and the vegetable matter, it is said, has been replaced, by a grey pulverulent tuff, probably washed into them by the rains of many centuries.

At Herculaneum, on the contrary, though the manuscripts may have been carbonized, probably by the wet which first penetrated into them from this aqueous inundation, yet any further decay has been prevented by the thick covering of tufa, and the writing is, therefore, in many instances, found to be legible.

No lava appears to have been ejected by this eruption; but it is not improbable that a cone occupying the site of the present one may have been formed by it, and that the mountain thus exchanged the appearance which seems to have belonged to it at the time of Strabo, for one more approaching to that which it exhibits at present.

Of this memorable eruption we have a lively description in the letters of the Younger Pliny, whose uncle, the celebrated Naturalist, fell a victim to his zeal in exploring its phenomena. Yet it is remarkable, that no notice is taken, either by this eye-witness, nor by any writer who lived near the time at which the catastrophe happened, whose Works have come down to us, of the fate of three such considerable towns, although the testimony of Dion Cassius, coupled with that of Martial, serve to identify their destruction with this particular epoch.

The second eruption appears to have happened in the year 203, under the Emperor Severus, and is described by Dion Cassius and Galen; the third in 472, which is said by Procopius to have covered all Europe with ashes, and to have spread alarm even at Constantinople. Other eruptions are recorded in the years 512, 685, and 993. The next, in 1036, is supposed to have been the first which was attended with an ejection of lava; in preceding accounts we hear only of sand and lapilli being thrown out.

Between that period and the commencement of the XVIIth Century, the mountain appears to have been only five times in a state of action; and in 1611, the interior of the crater, according to the report of Braccini, was covered with shrubs, and every thing indicated the profoundest tranquillity. Yet in 1631 one of the most terrible of its eruptions took place, which covered with lava the greater part of the villages lying at its foot, on the side of the Bay of Naples. Torrents of water also issued from the mountain, and completed the work of devastation. The volcano is likewise said to have been in activity in the years 1660, 1682, 1691, and 1698, from which time till the present its intervals of repose have been of shorter duration, though its throes, perhaps, have diminished in violence; for the longest pause since that time was from 1737 to 1751, and no less than eighteen eruptions are noticed in the course of little more than a century, several of which continued with intermissions for the space of four and five years. That of 1737 gave rise to a stream of lava, which passed through the village of Torre del Greco, and continued its course until arrested by the sea, at which time its solid contents were estimated at 33,587,058 cubic feet. Of the latter eruptions, one of the most formidable seems to be that of 1794, recorded by Breislac, himself an eye-witness of it, in his travels through Campania. The torrent of lava, that proceeded from the volcano, again destroyed the town of Torre del Greco, and advanced into the sea to a distance of no less than 362 feet, with a front of 1127 feet.

The eruption of 1813 has been described by Menard de Groye, and that of 1822 by Monticelli and Scrope. According to this latter Geologist, the whole of the upper part of the mountain was on this last occasion blown into the air, by the violence of the explosive force.

It must be confessed, that these descriptions, however interesting, leave us much in the dark with regard to the real nature of the phenomena; partly from the danger and difficulty of approaching the scene of operations, near enough to examine the products at the time of their ejection, but still more, from a want of due chemical knowledge in the observers themselves, such as should enable them to profit by the facts before them.

On this account, the remarks of Gay Lussac and Sir H. Davy, cursory as they are, exceed in scientific interest the more elaborate descriptions given by others; and if we abstain from noticing them at present, it is only because the results of their inquiries will appear more in place, if introduced hereafter.

Phlegrean Fields.

It is important, however, to observe, that since Vesuvius has resumed its activity, the numerous volcanic vents which exist on the other side of the Bay, (see pl. vi. fig. 2.) have sunk into a state of comparative inaction; for ancient writers, who are silent respecting the former, speak of the mephitic vapours of the Lake Avernus, as destructive to animal existence; and in earlier days than these, Homer pictures to us the Phlegrean Fields, as the entrance to the Infernal Regions, being placed at the utmost limits of the habitable world, unenlightened either by the rising or the setting sun, with groves consecrated to Proserpine, and enveloped in an eternal gloom.

Solfatara.

At present the only traces of activity that exist, are observable in the crater called the Solfatara, which occurs immediately above the little town of Puzzuoli. The rock of which this volcano is composed, is a hard and dark coloured trachyte, for the most part porphyritic, and containing more iron than belongs to this rock in general. It has given off a single stream of lava, which descends in the direction of the sea, terminating in an abrupt promontory called the Monte Olibano, and remarkable, as an instance of a true trachytic lava, consisting of little else than felspar, only occasionally intermixed with augite. It has been conjectured that it was the fruit of an eruption in the year 1198, said, though on rather doubtful testimony, to have taken place from the Solfatara.

The crater of this volcano is nearly oval, its greatest diameter being 2337 French feet, its smaller 1800 feet; and the continual evolution of sulphureous vapours, which has gone on from the earlier records to the present time, has naturally produced remarkable changes in the rocks surrounding it. The first stage of alteration seems to be a mere whitening of the mass, in consequence, doubtless, of the removal of the iron, to which its colour is attributable; in the next the rock becomes porous and fissile; when the process is further advanced, it acquires an honey-combed and spongy consistency; and at length it crumbles into a white powder, consisting almost entirely of silex. The rocks surrounding the Solfatara have consequently that white colour, which has given to them, in ancient times, the name of Colles Leucogei; and the saline ingredients, with which those in the crater itself are impregnated, are natural effects of the action of the sulphuretted hydrogen emitted, upon the alkali, the iron, and the alumina, which were its constituent parts. That a mountain so circumstanced should possess numerous internal cavities, is only a natural consequence of the continual penetration of corrosive vapours during the course of so many centuries; so that we may save ourselves the trouble of inquiring, whether the hollow sound, which it emits when struck, might be produced by any other cause, when the porous nature of the ground affords us so simple a solution of it.

Monte Nuovo.

The throwing up of a new mountain in the XVIth Century by volcanic agency, took place so much in the vicinity of the Solfatara, that it may seem to belong to its history. After a succession of earthquakes, and, as we are told, the bursting out of flames from the ground, in many places round about the Solfatara, there opened from the sea a gulf, from which, smoke, pumice, lapilli, and sand, were ejected with the noise of thunder. These masses fell in such abundance, that the sand was distributed, not only over Naples, but even to a distance of thirty miles from it, whilst the heavier and more bulky masses accumulated round the orifice to such an extent, that in two, or at most in five days, they constituted a conical hill, now called the Monte Nuovo, 8000 feet in circumference, and 413 in perpendicular height, with an internal crater about a quarter of a mile round, and in depth nearly equal to the elevation of the mountain itself.

The sand near the foot of the mountain, even underneath the sea, possesses so high a temperature, when brought up from a point, a little below the surface which touches the water, that we are led to believe the volcanic action to be still going on to a certain extent; an inference confirmed by the extreme heat of the water which gushes out from the rock in a cavern not far distant, called the Baths of Nero, which is sufficient to boil an egg, and amounts, according to Mr. Forbes, who has given the most accurate account of it from personal inspection, to 183° of Fahrenheit.

Such are the principal indications of volcanic agency, that have been handed down to us by history, as occurring in the neighbourhood of Naples; but the physical structure of the country is such as leads to a belief, that similar phenomena must have occurred elsewhere, since the country acquired its present general configuration.

Grotto del Cane.

The Lake Agnano, from its circular form, and the nature of the materials surrounding it, was evidently the crater of a volcano, which still communicates heat to a spring of water on its borders, and, probably, causes that continual evolution of carbonic acid, which fills the well-known Grotto del Cane. The Lake Avernus seems also to be of similar origin; and although there are no indications of a volcanic nature existing in it at present, yet the term, *graveolens Aornos*, applied to it by ancient writers, and the noxious effects of its exhalations upon birds that skimmed over its surface, prove that, at a period not very remote, sulphuretted hydrogen was emitted in large quantities from its spiracles.

The Monte Barbara and Monte Astroni are hills, which, from possessing a central and circular cavity on their summits, as well as from their figure and mineral constitution, are evidently derived from volcanic operations, although neither of them appears to have emitted streams of lava. The crater of the latter mountain is still so perfect, as to form a sort of natural inclosure nearly a mile in diameter, appropriated by the King of Naples, as a preserve for his wild boar and other animals destined for the chase.

Many other craters are alluded to by Geologists, as occurring in the vicinity of Naples, but they do not appear to be sufficiently ascertained; and several so designated are evidently mere hollows, derived from the action of water upon rocks, which, though of a volcanic origin, are of an earlier date, and of a somewhat different formation.

Puzzolana.

The whole country, indeed, from the sea to the base of the *Apennines*, appears to have been covered, at a time when it was yet submerged under water, by an immense deposit of *puzzolana* or volcanic tuff. This rock is for the most part of a straw-yellow colour, dull, and harsh to the feel, with an earthy fracture, and a loose degree of consistence. It contains imbedded fragments of pumice, obsidian, trachyte, and many other varieties of compact as well as cellular lava, the softer kinds often rounded, the harder mostly angular. It is separated into beds, by intervening layers of loam, pumice, or ferruginous sand, and, in one instance, according to Von Buch, calc-sinter. Shells are noticed as occurring in it, but they are rare, and bones of ruminating animals have likewise been discovered.

The height of this tuff in many places near Naples is very considerable; the hill of the *Camalduli*, which

rises to an elevation of 1513 English feet above the sea, consists of this material, and to the West of Naples it forms a sort of wall, so lofty and abrupt, that the former inhabitants of the Country apparently found it easier, availing themselves of the soft and friable nature of the stone, to cut through, than to make a road over it.

Such is the origin of the celebrated Grotto of Pausilippo, a kind of tunnel 363 toises, or 2178 feet in length, 50 feet in height, and 18 in breadth, which serves as the common medium of communication between Naples and the towns and villages to the West, said to have been originally formed by the Cimmerians, the earliest inhabitants of the Country, who dwelt chiefly in caves hewn out of the soft tuff, and were, therefore, led by successive steps to attempt more extensive excavations. The Romans appear to have merely enlarged, not to have originated it.

Now, though it need not be supposed, that this mass of tuff was originally deposited at equal depths over the whole surface which it covers, yet no one who examines the manner in which it has insinuated itself into the valleys, not only on the hills above Naples, as near Caserta, but also on the opposite side of the Bay, near Sorrento, and observes at the same time the extreme variation in its height, and the seemingly capricious manner in which it is distributed, can hesitate to suppose, that much which was originally deposited has been subsequently removed by the action of water; and, inasmuch as the general features of the country do not appear to have materially changed since the earliest periods of history, we are drawn to the alternative either of concluding, that the period, at which this mass was originally formed, goes back to a period beyond comparison more remote than that to which history reaches, in order to give time for causes at present in action to work such great changes, or that it has been effected by some more rapid agents of destruction than those at present at work. Either of these suppositions, it is clear, establishes a line of demarcation between the puzzolana and the volcanic rocks before enumerated, which is also confirmed by the indications we possess, that the latter was formed, whilst the greater part of the low country which it covers was still submerged under water.

But if, as seems obvious, the great mass of puzzolana near Naples has been deposited under water, the height above the level of the Mediterranean, which it not unfrequently attains, indicates the existence of great relative changes in the level of the sea and land, attributable either to a rise of the one, or a sinking of the other. The general consideration of this question belongs to another portion of the Treatise, but there are certain indications of a change of level in this district of so remarkable a nature, that it would be improper wholly to omit mention of them on the present occasion.

Temple of Serapis at Puzzuoli.

One of these relates to the appearances presented by a Temple near the town of Puzzuoli, supposed to be dedicated to Serapis, which appears to have twice changed its relative position to the sea contiguous, having been at some period subsequent to its erection sunk about twenty feet below its original level, and at some later period raised up again, nearly, though not altogether, to its former height. This inference is deduced from the circumstance, of the pillars which now remain erect, being perforated by pholades, at a height of about twelve feet from their pedestals, as if the sea had at one time stood at that elevation, which, it is evident, it could not have done at the time the Temple was built. Standing, as this fact appeared to do, alone, it was natural, that various hypotheses should have been suggested, in order to escape from so startling a conclusion, as that of the local rise and subsidence alternately of the spot of ground on which the Temple stood; but to such it is unnecessary to resort, now that we are assured or reminded of other proofs, showing an elevation of land at no remote period both on the North and South of Puzzuoli, of more than twenty feet, and of many similar subsidences to an equal extent in the same neighbourhood. Professor Forbes has the merit of first setting us right on this question, and his arguments have been extended and confirmed by Professor Lyell, in his recent Work, entitled *Principles of Geology* It therefore appears, that the effects of recent volcanic action have more than once altered the relative level of the sea and land in this neighbourhood, and we are, therefore, brought more readily to admit the possibility, that an extension of the same force, operating more generally, may have elevated the whole mass of the puzzolana, from the level of the sea, to the height at which it now appears.

Islands of Procida and Ischia.

To complete this brief sketch of the phenomena in the neighbourhood of Naples, we ought to allude to the Islands of Procida and Ischia, which belong to the same system of volcanos. (See pl. vi. fig. 2.) The former island seems to consist entirely of tuff, separated by beds of cellular lava, which are sometimes horizontal, and at others curved and contorted; but Ischia is somewhat more varied in its composition. It is for the most part composed of a rock which seems to consist of very finely comminuted pumice, reagglutinated so as to form a tuff. From the very fine state of division, however, into which it was reduced at the time when it underwent consolidation, a rock has often resulted of so homogeneous a texture, as to be considered a variety of felspathic lava, to which, mineralogically speaking, it bears a considerable resemblance, though we are, upon the whole, disposed to class it with the puzzolana of Naples, and the neighbouring Island of Procida. This formation is seen in every part of the Island, and forms the very summit of Monte Epomeo, which rises to a height of perhaps 2000 feet. In one spot, near the town of Foria, we observe intermixed with it huge blocks of trachyte, sometimes thirty feet in diameter, consisting of a congeries of crystals of glassy felspar, often without any kind of intermedium. In another, however, we observe a conical hill called the Monte Thabor, composed entirely of trachyte, and resting upon a bed of clay containing tertiary shells.

Ischia, however, presents evidence of volcanic operations of a more recent date, than can be assigned to those, which occasioned the formations above noticed.

Heaps of obsidian and pumice, substances almost unknown at Vesuvius, occur at the village of Castaglione, and have been traced by Spallanzani to a crater in the neighbourhood, called Rotaro. Still further to the East we cross the stream of lava, which issued from the side of the mountain in the year 1302, as we are informed by historians, remarkable for the large crystals of glassy felspar which are imbedded in it. Its surface is still undecomposed, and consequently barren, moss alone growing upon it, and that only in a few parts; a proof of the

number of ages required for bringing some lavas of a vitreous nature into a state fit for cultivation. This current may be readily traced up the mountain to the point whence it issued, which is marked by the existence of a crater, still named the Capo d'Arso.

Thus Ischia appears to have been subjected to volcanic action of as many different periods as the neighbourhood of Naples itself, its pumiceous conglomerate corresponding with the puzzolana, its trachytes with the rock of the Solfatara, and the lava of the Capo d'Arso with that of Vesuvius.

At present, the only direct indications of volcanic action are seen in the high temperature of the sand on the shore near Monte Vico, which ten feet below the surface is equal to 110° of Fahrenheit, and in the hot vapour which issues from the ground in various spots of the same neighbourhood. No eruption of lava has taken place since the XVIIth Century, though occasionally severe earthquakes are felt over the Island, more particularly, it is said, near the ancient point of emission of the Ischian volcano. (Forbes.)

We have dwelt upon the phenomena exhibited by this particular system of volcanos, somewhat more in detail than may be consistent with our general plan, conceiving, that a better notion may be conveyed of the nature of such operations, by particularizing some one district in which they are exemplified, than by any more abstract or generalized description; and certainly no one spot can be selected more illustrative, than the neighbourhood of Naples, as well from the variety of appearances presented, as from the facility with which they can be examined and compared. We must now proceed to specify more briefly the other principal foci of volcanic action, that have at one time or other existed in Italy.

Mount Vultur.

On the Eastern side of the Italian Peninsula, in the Province of Basilicata, near Melfi, rises a large isolated hill, called Mount Vultur, which at one time appears to have been a volcano of equal magnitude with that of Vesuvius on the opposite coast.

It is of a conical form, from twenty to thirty miles in diameter at its base, and with two craters on its summit. It is studded over with sundry parasitical cones, and has given rise to several considerable streams of lava.

The nature of the rocks, and the gaseous exhalations that abound in its neighbourhood, bespeak the former prevalence of volcanic action throughout this country, and may lead us to regard the district, as bearing a similar relation to the shores of the Adriatic, which the Campi Phlegrei, as they are termed, do to those of the Mediterranean.

Yet of the eruptions of this volcano, all records are lost in the darkness of antiquity, and we may perhaps refer them to that remote period, when, as has been conjectured, the foot of Mount Vultur was washed by the waters of the Adriatic, which now, from an accumulation of alluvial matter, has receded full thirty miles from it.

Assuming then the space comprehended between latitude 40° and 41°, as that portion of the Italian Peninsula in which volcanic operations are most rife, we will, in the first place, trace the same appearances Northwards, and afterwards Southwards of this central point.

Rocca Monfina.

First, then, near Mola di Gaeta, on the road between Naples and Rome, we recognise on the main land, North-East of the town of Sessa, extensive traces of volcanic operations, a considerable mountain, called Rocca Monfina, composed of lava and scoriæ, and retaining vestiges of a crater, appearing to have overspread the whole adjoining district with volcanic materials. Some of these appear to have been ejected since the country was inhabited by man; for the remains of an ancient city have been discovered in digging underneath the town of Sessa, of which, however, as well as of the eruption that destroyed it, no record exists.

Ponza Islands.

A few miles out at sea, to the Westward of Mola di Gaeta, lie the Ponza Islands, four of which appear to be entirely volcanic, consisting of trachyte, but are destitute of any crater, and without any stream of lava proceeding from them. They seem, therefore, rather to have been suddenly elevated from the bottom of the sea, than to have been formed by successive ejections of volcanic matter.

Papal States.

A low tract called the Pontine Marshes, divides these volcanos from the series of rocks near Albano, which in their structure and figure appear to have the same origin.

Near Albano are no less than four lakes, which seem to have been formerly craters.

The immediate vicinity of Rome, commonly denominated the Campagna, is composed of materials, which, though of a volcanic nature, appear to have been heaped together under water.

They consist of loose masses of lava or scoriæ, feebly agglutinated by fine volcanic sand, and alternating with arenaceous or calcareous beds, containing fresh-water shells, which seem therefore to have been deposited at the bottom of a lake. Hence although certain obscure notices of volcanic phenomena that occur in the history of ancient Rome, may lead us to infer, that the forces had not altogether spent themselves at the time the country began to be inhabited, yet it seems probable, that the eruptions occurred principally at a more remote period, when the Campagna was covered with water, and the higher parts of the country alone constituted dry land.

Evident traces of volcanic operations of an early period occur near Viterbo, and extend Northwards to Radicofani, but we have no records of their date, and but imperfect accounts of their effects.

North of Italy.

Indications of the same nature exist probably further North in the neighbourhood of Volterra, where occur pools of water called Lagunes, rendered boiling by the passage through them of sulphuretted hydrogen, which carries with it a little boracic acid.

But less equivocal proofs of volcanic agency are found near the foot of the Apennines in the neighbourhood of Verona, Vicenza, and Padua.

Extensive beds of volcanic tuff there occur, alternating with deposits charged with shells belonging to the newer tertiary period, with which is connected a group of trachytic rocks, constituting the Euganean Hills, which have burst through chalk. Every thing concurs to prove, that the whole or the greater part of these rocks were formed during the tertiary period, and consequently that they belong to the more ancient or antediluvian class of volcanos.

Having enumerated the principal foci of volcanic action North of Naples, we must retrace our steps, and

examine what indications of the kind are to be discovered to the South.

In Calabria, harassed as it has been by earthquakes, no genuine traces of volcanic agency have been discovered, but in the sea to the West of it occurs the group of the Lipari Islands, which are derived exclusively from this cause.

Lipari Islands.

These, however, although built up by the action of pre-existing volcanos, appear at present in a great degree exempt from their influence; the only remaining indications of the kind being those presented, by certain hot springs, which in this case we cannot hesitate to refer to such a cause, by a Solfatara in one of the smaller Islands, that of Volcano, and by the volcanic eruptions of Stromboli. The latter differs from most other burning mountains in the unintermitting character of its eruptions, which have indeed continued, from a period at least antecedent to the Christian Era, at intervals of a few minutes, but without any ejections of lava accompanying them.

The great mass of this, as well as of most of the other Islands, is composed of beds of volcanic tuff or puzzolana, occasionally penetrated by dykes of slaggy lava, which sometimes traverse the contiguous beds in a manner so conformable to the stratification, that, until traced to some extent, they might be mistaken for beds. Then, indeed, they display their true character, either by the disturbance they occasion in the beds which they traverse, or by some deviation from their original direction. (See pl. v. fig. 1 and 2.) The peculiar feature of the volcanic products of the Lipari Islands, however, consists in the abundance of pumice and obsidian, two different states of igneous productions, but rarely, if at all, met with amongst the volcanos of Naples.

In the South of Lipari, the whole surface is covered with pumice, which forms several considerable hills, and extends to the furthest point of the Island.

The obsidian also occurs in extensive beds, or forming a sort of breccia, angular masses of it being held together by a white earthy-looking paste, which is hard and gritty.

Sicily.

The Island of Sicily contains a great variety of rocks of ancient formation, in which nothing of a volcanic nature can be detected; but, from a period comparatively recent, igneous and aqueous groups seem to have gone hand in hand, in building up the rocks of which its surface is composed.

In the lower extremity of the Island there occur various alternations of volcanic with neptunian deposits, constituting a considerable tract, containing within it hills from one to two thousand feet in height. The volcanic rocks, though sometimes compact, are usually more or less cellular. The cells are occasionally empty, but at other times are filled with various crystalline minerals. The neptunian, according to Professor Lyell, contain marine shells, the greater part of which are identical with existing species, though a few are extinct, belonging to the newer pleocene era. Hence the volcanic eruptions, of which Sicily affords the records, numerous and extensive as they are, do not go back to an era more remote than the newer tertiary deposits. The great *marly* formation, indeed, which occupies a large surface in Sicily, and is characterised by immense deposits of sulphur, marine salt, gypsum, and other sulphuric salts, may probably be connected with certain great submarine eruptions; but we are prevented from clearly giving the date of this formation, in consequence of the absence from it of organic remains, with the existence of which the exhalations that gave rise to the sulphureous deposits seem to have been incompatible. In this formation occurs a phenomenon, commonly, though we conceive improperly, denominated, an *air volcano.* The most noted instance is at Macaluba near Girgenti; but as we shall consider in another place how far it may be regarded as connected with volcanic agency, we shall at present omit any more particular mention of it. It may serve to convey some kind of idea of the extended period during which volcanic operations have continued in this Country, when we are told, that the whole probably of Mount Etna belongs to a period more recent than the lavas of the Val di Noto. At its foot, indeed, are several isolated rocks; as, for example, the Cyclopean rocks off the coast near Catania, that of La Motte, &c. which seem to belong to the class of submarine lavas, and may perhaps be as ancient as some of those already mentioned; but Etna itself is made up, superficially at least, of a series of beds of lava and tuff, all of which possess the characters of subaerial volcanic products.

Yet according to the joint testimony of Sir John Herschel and Captain Smyth, this mountain has an elevation of about 10,000 feet, with a circumference of 90 miles, whilst, from the descriptions given by Professor Lyell of those valleys, which display the internal constitution of the mountain, and particularly that of the Val del Bove, the whole of that portion of it, which is exposed to view, appears to consist of a succession of lava beds and of tuff, intersected by dykes of trachyte and basalt. (See pl. iv. fig. 4.)

How vast then must have been the period employed in the heaping up of so enormous a mass of volcanic products, unless, indeed, the scantiness of time was compensated by increased energy of action, and the earlier portions of the history of this volcano were marked by more frequent eruptions than the later ones.

Yet, to conclude, that during the whole of this period no deluge could have washed over the country, seems an hasty assumption, implying a more thorough acquaintance with the force of the diluvial currents, and the extent of their operation upon the strata, than we can lay claim to, and likewise overlooking the manner, in which the effects produced upon the surface of this particular mountain may afterwards have been disguised by the eruptions that succeeded. We shall therefore content ourselves with that more general statement, which seems warranted by the facts before us, namely, that all the eruptions of Mount Etna, of which we have any cognizance, took place in the air, and that consequently the earliest of them do not in all probability date from so early a period, as those of the Val di Noto, which occurred, in part, at least, under water, and are covered with neptunian deposits of the tertiary period.

Island of Sciacca.

The neighbourhood of Sicily has likewise presented us with an example of one of those events, that occur, comparatively speaking, so rarely during the limits of human experience, namely, the breaking out of a volcano apparently on a new site.

On the 18th of July, 1831, a British vessel perceived in the Mediterranean, betwixt the town of Sciacca in Sicily and the Island of Pantellaria, a high irregular column of white smoke or steam, which, upon coming

near, proved to be caused by a small hillock of a dark colour, elevated a few feet above the sea, which appeared to be constantly discharging stones and dust together with vast volumes of steam.

The volcano went on increasing in bulk, till it had attained by the middle of August a circumference of 3240 feet, and a height of 107. It had a crater of 780 feet in circumference, and it consisted entirely of dark vesicular lava, with a few fragments of calcareous and other rocks, not of a volcanic nature, interspersed.

During the storms of the succeeding Winter, the loose materials of that portion of the Island, which had been elevated above the water, were gradually washed away, and no other monument of it now remains, except a dangerous shoal, with a circular patch of rock in its centre, about forty-two yards in diameter, on which there are for the most part two fathoms of water, but in one spot only nine feet.

It appears from the examinations of Hoffman, that the volcano in question lies in a line, which has been subjected to volcanic action from remote antiquity, ranging from the extinct volcanic Island of Pantellaria, by the sulphureous springs of Sciacca, to Mount Etna.

It is likewise important to remark, that, according to the observations of Captain Smyth, this volcano must have been elevated in very deep water, and that even now, in its immediate vicinity, the soundings indicate successively, ten, twenty, thirty, and forty fathoms.

Till within twenty yards, says Captain Swinburne, I got no bottom, and then eighteen fathoms water, whilst from another account it appears, that at a little distance the soundings were 100 fathoms. Lieutenant Lamert, of the French brig Armide, describes a bank extending to the North-East for a mile, which, he says, did not exist before the rising of the volcanic hill, and hence he infers, that, previously to the accumulation of the scoriæ by which its existence was manifested, the volcanic force had heaved up a portion of the bed of the Mediterranean. How far such a supposition is consistent with analogy, will be considered hereafter.

Grecian Archipelago.

If from Italy we turn to the Grecian Archipelago, the phenomena just described will be found to have been repeated, more than once, within the limits of authentic History, near the volcanic Island of Santorino.

Santorino itself (see plate vi. fig. 6) is of a semilunar form, and the horns of its crescent are nearly united, through the medium of two smaller volcanic Islands, called Therasia and Aspronesi, so that they together nearly encircle an area of above six miles in diameter, throughout a great part of which the sea is unfathomable. The beds on all these Islands dip at a slight angle towards the exterior of the group, just as would happen, if these Islands had constituted the walls of one vast crater, formed by the heaving up of the beds from the bottom of the sea, as Von Buch and Humboldt imagine to have been really the case.

Whether this be the true explanation, or not, of the position of the beds in the three principal Islands, will be considered afterwards; but a similar operation to the one supposed, although on a scale of inferior magnitude, appears to have taken place in more modern times, in the midst of the bay enclosed between the above-mentioned rocks.

Thus, 197 years before Christ, the island of Hiera, now called Palaia Kammeni, (plate vi. fig. 6,) is stated to have been thrown up from the bottom of the sea, and in the reign of Claudius, A. D. 46, another made its appearance, which in the year 726 was joined on to Hiera. In 1573, that called Little Kammeni was produced; and lastly, in 1707, New Kammeni was raised in the midst of the basin. The latter is distinctly said by the Jesuit Goree to have been heaved up from the bottom, as indeed the other Islands are reported to have been, and he alleges in proof of it, that a large quantity of fresh oysters were found adhering to the rock so thrown up.

Santorino, with its contiguous Islands, is chiefly composed of trachytic conglomerates, and tuffs covered with pumice, though in one part clay slate, and in another, according to Tournefort, granular limestone, appear.

From Santorino, a line of volcanic operations extends itself through Milo and Argentiere to the Eastern coast of the Peloponnesus, (see plate vi. fig. 5,) where before Modon (Methone in Argolis) are several rocks, called the Islands of Pelops, of a volcanic nature, and where also a promontory exists of a conical form, which appears at an early period of Greek History to have been heaved up. Ovid alludes to it in his *Metamorphoses*, and Strabo confirms, what otherwise might have been regarded as the fiction of a Poet, stating, that even in his time manifestations of volcanic agency still were observed.

Iceland.

To complete our account of those decided evidences of volcanic action, which are to be met with in Europe, we must refer to the Island of Iceland, where, from the earliest authentic records till the present day, volcanic operations have continued, on an extraordinary scale, and with intervals rarely exceeding twenty or thirty years between each. The volcanos in that Country are placed in general linearly, and the following ones are enumerated.

Hecla, the last eruption of which was in 1766.

Kattlagiau, which, after an interval of sixty-four years, had a violent eruption in 1823.

Eyafialla Jokul, which, after intermitting for a century, had an eruption in 1821.

Grimvatn, a lake which became the site of an eruption in 1716.

Skaptaa Jokul and Skaptaa Syssel, two contiguous volcanos, experienced violent eruptions in 1783, which ravaged a vast extent of the country adjoining them.

The lava made for itself a passage into the plain at the base of the mountain, by three streams about eight miles apart one from the other. These currents of lava, reuniting, covered a space of more than 1200 square miles. The ejections of ashes which terminated this eruption continued an entire year, during which the whole atmosphere was constantly darkened by thick clouds of cinders.

Other volcanic phenomena are frequent in Iceland. In 1783, a year memorable in its annals for the violence of the eruptions that took place in it, a new Island was thrown up, consisting of high cliffs, a mile in circumference, which, however, the following day, sunk again, leaving nothing but a reef of rocks, from five to thirty fathoms under water, to indicate its former site.

Geysers.

Although we have abstained in general from noticing the hot springs that occur in volcanic districts, not only as leading us too far, but likewise as tending to introduce amongst the fundamental facts upon which we

build a set of phenomena, the origin of which some may regard as problematical, yet are we induced by the obvious nature of the connection that subsists between the Geysers or hot springs of Iceland and its volcanos, as well as by the general interest which attaches to the former, to notice them amongst the effects of the same agency there exerted.

The Geysers are intermittent hot springs, which throw out at intervals a column of water, succeeded by copious volumes of steam.

The intermittent character of the phenomena may be seen explained on very simple principles by Sir George Mackenzie in his *Travels in Iceland;* and there is no doubt, but that the existence of subterranean cavities, serving as recipients for water in a heated bed of rock, and communicating with the surface by narrow orifices, would cause a generation of vapour, which occupying the upper portions of such caverns, would at intervals acquire elasticity enough to expel the water, and thus provide for itself the means of escape.

The water is strongly impregnated with silex, an ingredient almost universally present in hot springs, but in none so abundantly as in these; nor is it improbable, that the high-pressure steam which we know to be generated in this instance, may materially assist in reducing the silica to a state of solution, for it has been found, that even glass becomes quickly corroded by steam of this description, although it resists it when of ordinary elasticity.

The only other active volcano in the North of Europe is that in the Island of Jan Mayen, off the coast of Greenland. This, when visited by the Rev. Mr. Scoresby in the year 1817, exhibited all the marks of a recent eruption, and was found to consist of cellular lava, of tuff, and of scoriæ.

On the summit was a crater, no less than 500 feet in depth, and about 2000 in diameter.

Extinct Volcanos of Europe.

Having now enumerated the several sites of volcanic operations in Europe, which still continue in some part or other to exhibit marks of activity, we must next take a rapid survey of those in which the same forces have at some former period incontestably been at work, but where they seem, so far as human experience goes, to have expended themselves.

In this review we shall omit all, excepting those extinct volcanos which have operated apparently under similar circumstances to those of the present day, passing over altogether the consideration of such rocks, as, though inferred to be volcanic, differ nevertheless from the products of existing ones, in a manner which seems only explicable, by supposing an alteration in the circumstances under which they were ejected.

Portugal.

In this review, it may be convenient to begin with the most Southern portion of Europe, namely, the Spanish Peninsula, tracing up the indications of the same kind that occur until we reach Germany, above which, it may be observed, no phenomena of the kind are observable; for although in various parts of Great Britain and Ireland, in the Hebrides, the Faroe Islands, and even in the Scandinavian Peninsula, trap rocks of various kinds are extensively developed, yet these, for reasons already assigned, do not come under our present consideration, being nowhere distinctly proved to be produced, as the others have been, in the open air.

On the Eastern side of the peninsula, we meet with volcanic appearances, in the Province of Algarve, near Cape St. Vincent; and, on the road from Cintra to Maffra, near Lisbon, occur alternations of semivitreous basalt with tertiary limestone. The occurrence here of the former is worth noticing, from the formidable earthquakes with which Lisbon has more than once been visited.

Dolomieu notices also in the Province of Biera, certain volcanic appearances throughout the chain of mountains called Sierra de l'Estrella, but we are not aware, that they have been examined by any more recent observer.

Spain.

On the Eastern side of the Peninsula occur indications of volcanic action at Cape de Gaieta, near Almeira, and further North, as it is said, in the mountains above Alicant, where earthquakes are frequent and severe; but the most decided and the best established indications of the kind occur in Catalonia, near the town of Olot. No sooner have we descended the Northern declivity of the Pyrenees towards the Eastern extremity of that chain, than we meet with a volcanic district of about fifteen geographical miles from North to South, and about six from West to East, the vents of the eruption ranging linearly in the former direction, whilst the currents of lava have descended in the latter.

There are about fourteen distinct cones with craters, most of them as entire, as those in the neighbourhood of Naples, or on the flanks of Etna. They have broken through sandstone, shale, and limestone, belonging to the secondary period, but appear to be posterior to the most modern tertiary strata that exist in the neighbourhood, being covered only by the detritus of their own and the contiguous rocks. In the XVth Century the whole of the town of Olot, with the exception of a single house, was thrown down by an earthquake, accompanied, as it is said, by an eruption; but this latter circumstance is regarded by Professor Lyell as apocryphal; and there appears to be no certain record, as to any of the volcanos of this district having been in an active state during the historical period.

France.

Traces of volcanic action are found immediately North-East of the Pyrenees, in a little hill, composed of scoriæ, and possessing a regular crater, which borders on the sea near the town of Agde, between Beziers and Montpellier. Thence, a line of volcanic rocks, of various degrees of antiquity, extends into the Cevennes, and connects itself with a more extensive igneous formation in the Vivarais. (Dep. d'Ardeche.) The latter extends itself into the contiguous Department of the Haute Loire, where round the town of Puy it is most fully developed; and the same appearances are renewed in the Cantal, near St. Flour, whence they occupy a wide extent of country, until, after forming the elevated range of Mont Dor and the mountains about Clermont, they terminate Northwards near the town of Riom.

To give any thing like a particular account of the rocks comprising those extensive districts, would occupy too much space, but it may be well to state briefly the general characters, that distinguish in all of them the volcanic formations into two great classes.

There is then, in Auvergne, in the Vivarais, and even in the vicinity of Puy en Velay, an extensive group of volcanic hills, possessing craters, and having streams of lava proceeding fr   them, which in no respect diff r,

Geologically speaking, from the products of igneous action which we witness daily forming before our eyes. Though no records remain of the period in which these lava streams were ejected, still it is evident, from their shaping their course in conformity to the valleys of the district, that no great changes in the external configuration of the country can have taken place, since the period of their ejection; so that this one circumstance constitutes a broad line of distinction between these and other rocks in the same district, which have themselves been acted upon by the causes, that have excavated valleys in the contiguous formations.

It may, indeed, be true, that some of these volcanic rocks are themselves excavated to a considerable extent by the rivers which flow over their surface, as is remarkably exemplified in the Vivarais, where certain lava streams, which manifestly flowed, since the great features of the country had become as they are found at present, have nevertheless been themselves scooped out, to the depth of 70 or even 100 feet, by the action of the streams that flow at their foot.

Practically speaking, however, no one can confound the ravines, which have been channelled in lava streams of more modern date, with the valleys, by which the rivers which excavated these ravines have their course determined; so that the distinction adverted to may be admitted on the score of convenience, even by those who object to the principle on which it is founded. Whether, indeed, the valleys in question have been produced by the continued operation of the same streams, to which we refer the ravines, is a question more fitted for another part of this Treatise; but, as the majority of English Geologists, in speaking of valleys of this description, and of the detritus resulting from their excavation, still retain terms, which appear to recognise the principle of their having been produced in a different manner, designating them, as diluvial valleys, diluvial deposits, &c., so we shall adopt a similar nomenclature with reference to the volcanic products of Auvergne, speaking of those which are posterior to the valleys of the district, as postdiluvial, and those which are themselves hollowed out by valleys of the same character with the contiguous rocks, as antediluvial formations.

The postdiluvial volcanic products, then, are distinguished by the same characters, which belong to the modern lavas of Etna or Vesuvius, and may be traced to craters often preserving nearly unimpaired their original integrity. In Auvergne alone little less than seventy of them have been enumerated, which possess, in general, a great uniformity of character, and evidently all belong to an epoch, at which the adjoining country had already become dry land. In the neighbourhood of Clermont, however, are five conical hills, (see pl. iv. fig. 5,) in the midst of a group of these volcanos, possessing a striking difference in their aspect and constitution. They are composed of an earthy and pulverulent variety of trachyte, called domite, are altogether destitute of craters, but in general lie detached, in the midst of a sort of amphitheatre of volcanic hills, consisting of scoriform pyroxenic lavas.

The loftiest of these mountains, the Puy de Dome, gives its name to the Department in which it is situated; the others, the Puy de Sarcouy, the Grand and Petit Cliersou, and the Puy de Chopine, lie contiguous, but are so detached one from the other, that it would seem impossible to imagine them parts of a formation that once spread over the intervening country, even if there were not other difficulties in the way of such a supposition. It was the appearances of these rocks, that originally suggested to Von Buch, in an early stage of his career, the theory, which he has since applied to other volcanic formations in different parts of the World, with regard to the heaving up of conical masses of rock, previously softened, by the force of the elastic vapours generated by volcanic operations. The phenomena presented by one of these hills, the Puy Chopine, strongly confirm this view; as we see there an intermixture of trachyte, with granite, and other primitive rocks in various states of alteration, according, as it should seem, to the different degrees, in which they have been severally affected by the igneous action, to which their elevation is attributable. The Puy itself is situated in a sort of crater, the walls of which are composed of scoriform lavas of the ordinary description. The five domitic hills just alluded to, may, perhaps, belong to the postdiluvial class of volcanos, but at a short distance from them occurs an elevated and extensive table land, called the Mont Dor, the great mass of which consists of trachyte, of a more compact and crystalline description, and clearly of an older date. Vast masses of tuff, similar to the puzzolana near Naples, accompany it, and the whole is capped, either with basalt, as is the case at Mont Dor, or by porphyry slate, as in the neighbouring Department of Cantal, where this same formation extends itself. The whole rests upon the freshwater limestone belonging to the tertiary period, which, however, in a few places, alternates with it, and it is intersected by valleys as wide and as profound, as those which traverse any of the older rocks in the contiguous country. These, therefore, we shall venture to denominate antediluvial, in order to mark the difference, both in character and in age, that exists between them and the rocks before mentioned. These last, indeed, appear from various circumstances to have been formed under water, and can, in no instance, be traced to any crater or focus of eruption; whether it was, that the changes that have subsequently taken place in the country obliterated the traces of them, or, what is more probable, that they were originally ejected through the medium of dykes, and under a pressure which confined the focus of eruption within the narrowest limits.

Be that as it may, it is certain, that the appearances presented by the volcanic rocks of Mont Dor and Cantal, are of a totally distinct character from those of Vesuvius or Etna. Instead of narrow bands of lava covered with beds of tuff or loose scoriæ, these mountains present continuous beds of trachyte, basalt, and conglomerate, mantling round the axis of the chain, and interrupted only by the valleys which intersect them. How these rocks could have been brought into their present inclined position, will be a matter for subsequent inquiry; at present, we are only concerned with the circumstances, in which the structure of these mountains differs from that of the volcanos now forming under our eyes.

The structure of the volcanic district in the Velay and Vivarais is of an analogous kind, consisting of immensely thick deposits of volcanic tuff, generally resting on a fresh-water tertiary limestone, and of rocks of trachyte and porphyry slate, which appear to be of subsequent date, and to have forced themselves through the tuff which they overhang.

The depth of the valleys, excavated in this great tufaceous deposit near the Puy, serves to evince, either the long continuance, or the energetic action of the causes

which have since affected it, and the irregularly abrupt and almost pyramidal form, which belongs to some of the detached hillocks, which lie scattered over the valley, as that on which the cathedral and part of the town of Puy is built, and as the contiguous rock of St. Michael, evinces the irregular manner in which this material decomposes, and the firmness with which its parts in certain positions cohere. The last-mentioned districts also, like those of Auvergne, display many indications of volcanos possessing a more recent date, such as craters still remaining in all their original integrity, beds of scoriæ which have been ejected, as at present, in the open air, and lava streams, which have descended into the valleys in conformity with the present configuration of the country. Some of these lava streams, however, are themselves deeply channelled by the rivulets that flow across them, and being composed of compact and columnar trap, the sides of the ravine are flanked by basaltic colonnades.

Germany.

In proceeding to Germany, we may remark, that a chain of primary rocks, with many secondary formations superposed, stretches with certain interruptions through the heart of the country from East to West, of which the several portions are respectively distinguished by the names of the Thuringerwald, the Fichtelgebirge, the Erzgebirge, the Riesengebirge, &c. In connection with this great back bone, as we may term it, of Germany, and on either side of it, occur groups of volcanic cones, or other indications of an igneous character, whilst to the North of the above line they are entirely wanting.

Eyfel Volcanos.

Beginning with the Rhenish Provinces, we observe immediately at the foot of the Ardennes, in a district called the Eyfel, a cluster of little volcanic cones, composed, for the most part, of loose scoriæ, and frequently having very perfect craters, which sometimes serve as reservoirs for the waters of the country, and thus are converted into lakes; at other times are dry, and exist in all their original integrity. Accordingly, notwithstanding the silence of history concerning their eruptions, we can scarcely dispossess ourselves of the idea that they were the work of a recent period, and are persuaded, that they at least belong to as late a Geological epoch as that which we have assigned to some of the volcanos of Sicily and Naples.

They are remarkable for the general absence of any lava-currents proceeding from them, being for the most part mere aggregates of scoriæ, or a sort of volcanic tuff, made up of pulverulent materials ranged round a central aperture. They in some cases consist merely of the ordinary rocks, upheaved, but in other respects but little altered in appearance. The above, however, appear to be the only vestiges of volcanic action in Germany, that admit of being clearly referred to the same modern epoch, the other rocks, which bear marks of a similar origin, being destitute of craters, and more compact in their structure.

Siebengebirge.

On the Eastern bank of the Rhine, opposite to Bonn, rises abruptly from the borders of the river the chain of mountains, called the Siebengebirge, from the seven principal peaks that strike the eye from a distance.

They are composed, partly of basalt, and partly of trachyte, which appear to have been protruded through the schists, that constitute the fundamental rocks of the district. The superposition of the volcanic products to the brown coal so extensively met with in this Province, is, however, decisive with regard to the tertiary origin of this deposit. The Siebengebirge are, in fact, a prolongation of the extensive basaltic formation of the Westerwald, which again is connected with another considerable volcanic district North East of Frankfort, called the Vogelsgebirge.

From the latter, the isolated basaltic cones of Frankfort and Hanau on the one side, and of Cassel and Eisenach on the other, seem to be ramifications. In many of these basaltic rocks, the compactness of structure is quite equal to that of the trap in older formations, but in other cases, they are associated with vesicular lavas, which occur less frequently at least, if they are not entirely absent, in the latter. The contact between the volcanic material, and the contiguous stratum, has often been productive of very striking changes in the structure of the rock, rendering, in particular, the sandstone hard and prismatic, just in the same manner as is done in some parts of this country by artificial heat.

Higher up the Rhine, occur several groups of rocks possessing a similar origin to the above. In the Odenwald, near Heidelburg, rise some eminences from the midst of the new red sandstone, in which basalt is found associated with augite rock; and near Freyburg, in the Brisgau, is the series of hills, of which that called the Kaiserstuhl is the most prominent, destitute of craters, but containing, intermixed or associated with compacter rocks, vesicular products much resembling recent lavas. Lastly, a few miles to the North of the Lake of Constance, is the commencement of another chain of basaltic and porphyritic cones, connected with which, are certain overlying masses of basalt in Wirtemberg, along the chain of the Rauhe Alp South of Tubingen. These latter, however, have more of the characters which mark the older trap rocks.

In the Rhöngebirge, a group of mountains East of Fulda, a continuation of the same volcanic formation has been noticed, though recent observers have pronounced it to be destitute of craters; and at the Fichtelgebirge, on the North-Eastern limit of Bohemia, occurs a series of basaltic cones extending from Egra to Parkstein.

The same rocks may be traced to Toeplitz in Bohemia, and to the Riesengebirge in Silesia, whilst on the lower side of this chain of mountains, which is there called the Erzgebirge, occur several platforms, cones, and domes of basalt, overlying the other rocks of the country, and therefore posterior to them all. It was these, which impressed Werner with the idea of the aqueous origin of trap, from the marked contrast he observed between the characters and position belonging to these rocks, and to the volcanic products of the present day.

Lastly, on the Western border of Moravia, near the frontier of Hungary, is a small basaltic deposit near Banow.

The above statement, it is feared, affords but an imperfect enumeration of the several sites, in which volcanic action has at former periods of the Earth's history manifested itself throughout Germany, whilst it is probable, that many of the trap rocks alluded to belong to the class, which has been in general omitted, namely, that of submarine lavas; nevertheless it may have its use, in point-

ing out an important fact in the natural history of volcanos, namely, the *linear* direction which they assume, and their connection with the leading chains of mountains in the country, corresponding also with the direction, in which the shocks of earthquakes are most commonly propagated, and in which hot springs occur.

Hungary.

Connected with some of the more Eastern of these groups, is a very extensive volcanic formation in the North of Hungary, consisting of five principal groups, the first of which, in the district of Schemnitz and Kremnitz, occupies an elliptical space of about twenty leagues by fifteen.

The second, a smaller group South of the preceding, forming the mountains of Dregeley, near Gran, on the Danube.

The third, a mountain group known by the name of Matra, situated in the heart of Hungary, East of the former.

The fourth, a chain which commences at Tokai, and extends North to the heights of Eperies, in length twenty-eight or thirty leagues, and in breadth about five or six.

The fifth is that of Vihorlet, East of the foregoing group, which is connected with the trachytic mountains of Marmarosch on the borders of Transylvania.

The latter form a wide range extending from Vasarhely near the Western declivity of the Carpathians along the line of the river Marosch, nearly to Cronstadt on the frontiers of Walachia.

Now it is remarkable, that throughout the whole of this tract, studded as it is with indications of volcanic agency, no evidences of a continuance of the same has been discovered, unless the Solfatara of Budoshegy in Transylvania be regarded in that light. Neither do any craters exist, except at the Southern extremity of this latter chain, and perhaps near the Lake of Balaton in Hungary.

In other situations, the prevailing rock is trachyte, which occurs in a state of greater developement, and consequently under a greater variety of aspects, than any where else in Europe. This is associated with pumice and other cellular products, which indicate that it was not formed under deep water; an inference confirmed by observing, in the pumiceous conglomerates derived from the trachyte itself, shells of the same age as those met with in the basin of Paris. (Beudant.) It would seem then, that the volcanic eruptions of Hungary took place at a period, when the low country was overspread with extensive fresh-water lakes, of which that of Balaton, near which locality they appear to have continued longer than elsewhere, is the only considerable remnant.

In Styria also, a little to the South east of Gratz, occurs a series of volcanic hills, grouped round a central trachytic eminence, the Gleichenburg. (See pl. v. fig. 10. for an ideal section of the arrangement of the strata round the central trachyte in that Country.) And it is probable that others exist in many parts of Turkey.

It is certain that on either side of the Sea of Marmora, from the Dardanelles upwards to Constantinople, occur volcanic rocks, whose porous and vitrified aspect announces a modern origin, but they appear to be destitute of craters.

On the Volcanos of Asia.

Asia Minor.

With the line of extinct volcanos on the shores of the Bosphorus is probably connected that which has been described by Mr. Webb as existing in the Troad, and which is developed still more extensively in the neighbourhood of Smyrna. The latter district was called, according to Strabo, the Catacecaumene, from its burnt and arid appearance, nor does this ancient Geographer hesitate, to refer the characters it bears, to the action of fire proceeding from the earth. (*απο γηγενους πυρος.*) He also speaks of a Plutonium or cave exhaling carbonic acid, which still appears to exist in this neighbourhood, a proof of the long continuance of processes resulting from this deep seated cause.

Dead Sea.

In Syria, and especially in the neighbourhood of the Dead Sea, occur indications of volcanic action, belonging apparently to a still more recent date; at least, if we are justified in supposing the awful event, relative to the destruction of the cities of the Pentapolis, recorded in the Book of Genesis, of which the Dead Sea is stated as the result, to have been brought about by the immediate operation of volcanic forces.

The exact mode, in which it came to pass, that the River Jordan, which appears at one time to have flowed into the Red Sea, (see pl. vi. fig. 1.) created that expanse of waters which now occupies the valley of the Pentapolis, and in which the stream at present loses itself, must of course continue a matter of surmise, until some adventurous traveller shall have examined the country South of the Dead Sea with Geological eyes. It may, however, be suggested, that if one of those volcanos which, we are told, exist South of the Dead Sea, had given rise to a current of lava of considerable thickness, which took possession of the bed of the river, the waters of so considerable a stream, confined within the compass of the valley, would have spread themselves over it, until they had converted what was before a fertile plain into a wide waste of waters.

Such a supposition is at least agreeable to analogy, for Auvergne alone supplies us with more than one instance of a lake being produced, owing to the ponding up of the waters of a river by a stream of lava; nor ought it to be objected to as inconsistent with the authority of Scripture, which in this, as in other instances, only informs us, with regard to the reality of the event, and the moral end it was intended to answer, without seeking to enlighten us relative to the physical means by which it was brought about.

Dr. Clarke and other travellers notice similar volcanic appearances in Palestine; and some of the sacred Prophets, from certain allusions that occur in their writings, appear to have been eye-witnesses of, or at least familiarly acquainted with, volcanic phenomena.

Red Sea.

The existence of extinct volcanos at Sherm in the Peninsula of Mount Sinai, may enable us to connect the phenomena exhibited in Palestine with the active volcano of the Island of Zibbel Teir in the Red Sea, and with other appearances of the same kind that have been noticed in Arabia.

Central Asia.

There is reason also to believe, that volcanic operations may be traced along a line, where we should be least disposed to anticipate their occurrence; namely, across the centre of the great Asiatic Continent. To the West

and South of the Caspian lies the chain of the Caucasus, which presents in many parts indications of the kind. Mount Ararat itself is stated to be an extinct volcano, and some mountains further North, near the River Kuban, are stated to be composed of materials similar to those of the trachytic hills near Bonn. Demavend, the highest peak in the chain of Elburs, itself a branch of the Caucasus, is an extinct, if it be not now an active, volcano, for it is reputed sometimes to emit smoke, and Morier mentions traces of the action of fire South of this point, between Teheran and Ispahan.

If we cast our eye on the mass of Central Asia, we may observe a series of lakes or seas, of which the Caspian is the most Eastern, extending far into the Chinese territory. These lakes are indications of a great depression of the Earth's surface, which Humboldt conjectures to extend Northward to the Frozen Sea, at the mouth of the River Ob, on the Eastern side of the Oural mountains, and which stretches Eastwards between the two nearly parallel ranges, the Altai and the Teen-shan or Celestial mountains. This depression is not merely a relative, but an absolute one, for Engelhardt and Parrot have ascertained by barometrical measurement (and the same has been confirmed in a very remarkable manner, by the observations made on the boiling point of water by a recent English traveller Captain Monteith) that the Caspian, which occupies its present level, is below the surface of the Ocean; and the existence of salt in the soil as well as in the lakes, together with the presence of sea-shells identical with existing species, indicate, that at no very remote era, Geologically speaking, a large portion at least of this tract was occupied by water, of which the Caspian, the Lakes of Aral, Baikal, &c. are the residue.

Now it is in this depressed portion of the great Asiatic Continent, that the volcanos, which are reputed to exist in Central Tartary, have broken out.

The extinct volcano of Aral Toobe, which is an Island in the Lake of Alakul, and the Solfatara, as Remusat calls it, or the active volcano, as Humboldt is inclined to consider it, of Pecchan or the White Mountain, both lie on the Northern declivity of the Celestial Mountains, the latter not very distant from the Lake of Issikoul, which appears to be about double the size of that of Geneva. It had an eruption in the VIIth Century. In its neighbourhood is a mountain called Ourumski, five leagues in circumference, which produces immense quantities of sal-ammoniac, and which probably is the crater of a Solfatara, or half-extinguished volcano. Near the Lake of Darlai also is a small mountain full of fissures rising out of a plain adjoining the banks of the River Kobok, in which the same salt sublimes.

Eastward of Pechan, the whole Northern slope of the Celestial Mountains presents volcanic phenomena, for lava and pumice abound, and various exhalations are here and there emitted.

Southward of the same chain also occurs the volcano of Tourfan, in latitude 43° 34′, called Ho-Tcheou, town of fire; though it seems doubtful, whether this be in an active condition at present. It is said to be in the midst of several considerable, though, according to Humboldt, shallow lakes, and produces large quantities of sal-ammoniac. Thus Humboldt concludes, that we are acquainted with a volcanic territory in the interior of Asia, the surface of which is upwards of 2500 square leagues, and which is distant 300 or 400 leagues from the sea; a remarkable exception certainly to the general fact of the propinquity of volcanos to the Ocean, though one not more extraordinary, perhaps, than the position of Jorullo in the centre of Mexico, seeing that all these volcanos, in consequence of their mutual connection, may be supposed to communicate with the lakes, that occur in the longitudinal valley in which they are situated, just as the Mexican volcano, by its connection with the other vents which stretch across the American Continent, appears to be with either Ocean.

Kamtschatka.

The exact condition, however, in which the volcanos of Central Tartary now continue, must, after all, be open to some uncertainty, seeing they have never yet been examined by any European traveller; and the only ones, whose existence on the Continent of Asia can be looked upon as ascertained, are those in the Peninsula of Kamtschatka, where three in a very active condition are enumerated

Thence we may, to all appearance, trace a chain of volcanic operations along the Aleutian Islands to the Peninsula of Alaschka, in North America, where indications of the kind are said to occur.

Among the Aleutian group, Langdorf has described a rock near the Island of Unalaschka, 3000 feet in height, consisting of trachyte, which made its appearance at once from the bottom of the sea in the year 1795, an occurrence, which may serve to render more credible the traditions which have reached us, as to the rise of new Islands elsewhere in the sea.

The volcanos of Kamtschatka are connected again with a very extensive range of similarly formed mountains in Japan, through the medium of those of the Kurule Islands, in which no less than nine active vents are enumerated.

Indian Archipelago.

Other links in the same extended chain of igneous operations may be observed in the Islands of Loo-Choo, probably in that of Formosa, and in others connecting Japan with the Philippine group. (See pl. vi. fig. 4.)

Luçon, the largest of these, contains three active volcanos, one of which, that of Taal, South of Manilla, had an eruption in 1754. The Islands of Fugo and Magindanao likewise contain each a burning mountain. The line is thence prolonged through Sanguir and the North-east extremity of Celebes, by Ternate and Fidore to the Moluccas. In Sambawa, belonging to this latter group, one of the most formidable eruptions ever known has been recorded by Sir Stamford Raffles, the effects of which were felt over a space of 300 miles, extending itself through the whole of the Molucca Islands, Java, &c.

From Sambawa a great transverse line of volcanic operations may be traced from East to West. On the West it passes through Java, then bending Northwards is prolonged through Sumatra, and terminates in Barren Island, in the Bay of Bengal, about the 12th degree of North latitude. (See pl. iv. fig. 4.) To the East of Sambawa the volcanic range extends itself to Banda and New Guinea, and then expands over the greater part of the Pacific Ocean, which appears to constitute but one great theatre of volcanic operations.

Pacific Ocean.

The Islands dispersed over this vast expanse may indeed be referred to two classes; those of low elevation, which appear to consist entirely of coral reefs, and those of more considerable height, chiefly consisting of volcanic peaks. But even the former appear to be in the

great majority of instances based upon submarine volcanos; for it seems to be ascertained, that madrepores will not commence their building operations at a depth greater than about twenty feet below the surface of water; and where the subjacent stratum has been explored, a rock of volcanic nature has in general been detected as its basis. Among the loftier Islands of the Pacific Ocean occur some of the most remarkable volcanos of the Globe, especially that of Kirauca in the Island of Owhyhee, described by Mr. Ellis, which appears to be in a state of incessant activity, and Mouna-roa, an extinct one, the height of which is calculated at 16,020 feet.

Other volcanos are stated to occur in different parts of that extensive tract, as far as New Caledonia and New Hebrides. The separate mass of New Zealand, with which Norfolk Island is connected, may be viewed as the Northern extremity of the bulwark; its Eastern can hardly be fixed at any nearer point than the coast of America, since it appears, that an active volcano at present exists among the Galapagos only 10 degrees West of Quito.

On the Volcanos of Africa.

Nor are volcanic phenomena limited to those Islands only which lie Eastward of the Indian Archipelago; for we have reason to believe, that a large proportion of those which may be regarded as dependences upon the Continent of Africa, are derived in great measure from the same cause.

How, indeed, the case may stand with regard to the largest of them, Madagascar, our imperfect acquaintance with that extensive tract affords us but few data for determining; though Ebel (Bau der Erde) states the existence there of a volcano, and some specimens that were sent from thence to the Geological Society seem to corroborate his statement.

We know, however, that the smaller Islands in its vicinity, namely, the Mauritius and the Isle of Bourbon, are made up entirely either of volcanic materials, or of the coralline limestone of modern growth. In the centre of both these Islands rises a conical mountain, constituting the most elevated point of each; but in the Mauritius there is no semblance of volcanic action at present, whereas, in the Isle of Bourbon exists one of the most active vents in the World; for since 1785, the year in which a register of its eruptions was commenced, up to 1801, at least two lava streams annually have been thrown out from the sides of the mountain, and of these, eight have reached the shores of the sea. These currents of lava from the lower part of the mountain are followed by ejections from the craters situated on its summit, and amongst the substances thrown out is that filamentous variety of pumice, which so resembles spun glass in appearance and flexibility.

These lavas are of a trachytic character, but the Island itself is principally composed of beds of compact and amygdaloidal basalt, alternating with tuffs, the whole being intersected by basaltic dykes.

Besides this active volcano, an extinct one of larger size, called Les Fournaises, exists in the West of the Island. On the Continent of Africa itself, we have no well-ascertained instance of volcanic agency, though the German traveller Rüppell reports, that in Kurdofan, 150 leagues from the Red Sea, and, consequently, far in the interior, a conical and smoking mountain was stated to him as existing.

We will proceed, therefore, to the Islands on the Western side of Africa, beginning with St. Helena, which appears to be made up of coralline limestone and volcanic matter, the disposition of the latter being towards the centre of the Island, where a crater shaped cavity exists.

The Island of Ascension, of Tristan d'Acunha, and that called Gough's Island, are also volcanic, and so likewise are those of Fernando Po and Prince's Island, in the Bight of Biafra.

The Cape Verd Islands are composed chiefly of tertiary limestones and volcanic products, but no active volcano exists amongst them, except in the Island of Fuego, which is reported to be in a state of constant activity.

Canary Islands.

Ferro, the next in the series, is volcanic, and a burning mountain burst out in it in 1677, which again, in 1692, caused an eruption of six weeks' duration.

Indeed, the whole group of the Canaries seems to be placed within the sphere of the same submarine volcano; for although vestiges of other rocks are met with, as of granite and mica slate in Gomera, and of limestone in Great Canary, Fortaventura, and Lanzerote, yet none of these Islands are exempt from occasional manifestations of the same igneous action.

Teneriffe.

In the Island of Teneriffe we see exemplified, almost every variety of volcanic product that elsewhere exists.

The Peak, a conical mountain which rises to the height of about 12,000 feet, is itself composed of trachyte, but it rises out from the midst of rocks, consisting of basalt and the compacter forms of pyroxenic lavas.

The crater of the Peak has given rise to ejections of vitreous lavas, partaking of the character of obsidian, together with loose masses of this substance and of pumice.

At present, however, the principal eruptions take place from the flanks of the mountain, and at a much lower level, namely, from the parasitic cone of the mountain Chahorra, which bears the same relation to the Peak, that the Monte Rosso does to Etna; and it is remarkable, that pumice never has been thrown out by any of these later paroxysms, the products of which are lavas or loose masses, possessing a stony aspect, a black colour, and a large proportion of pyroxene; substances, in short, bearing the same relation to the compact traps constituting the basis of the mountain, which the trachytes do to the clay porphyries found amongst older rocks.

The remainder of the group, as described by Von Buch, appears to consist of submarine lavas similar to those which constitute the base of Teneriffe; in the Islands of Great Canary, of Palma, and others, the beds composing them rise in all directions upwards towards the centre of the Island, where occurs a circular cavity, called a Caldera, similar in shape to a crater, but destitute of lava currents, more profound and abrupt, and of greater circumference.

The Caldera in the Isle of Palma is 5000 feet in depth, and about two leagues in diameter, and from its summit, the edges of the beds, of which the Island is composed, are seen in regular succession, intersected by a network of basaltic dykes.

Another prominent feature in these Islands, is the occurrence of deep and abrupt valleys called Barancos, which intersect the strata, radiating in all directions

from the centre to the circumference. Their precipitous escarpments, and the absence of any streams running through them, plainly denote that they owe their origin, not to water, but to something connected with the peculiar physical structure of the Island; and Von Buch observes, that both the position of the rocks themselves and the barancos with which they are intersected, admit of a simple explanation, if we suppose a succession of submarine lava-beds to have been upheaved by the action of elastic vapours from the bottom of the sea, the Caldera, towards which all the strata rise, being the point that first yielded to the force applied, the Barancos, a natural consequence of the splitting, which would be caused by the increase of surface over which the rocks were spread, when raised up from their original horizontal position at the bottom of the sea.

As this mode of explanation has, however, been lately disputed, we shall defer the consideration of it to a later portion of this Treatise, and shall, therefore, only remark that the Caldera of Vandama, in the Island of Great Canary, is composed principally of trachyte, (see Von Buch, p. 261.) and therefore could not have been built up by a number of successive eruptions, as has been the case with some craters. (See pl. iv. fig. 3.)

The Island of Lancerote is somewhat differently formed from the rest, presenting a series of not less than twelve little volcanic cones, three or four hundred feet in height, composed of harsh, porous, sharp lapilli, provided each with a crater, lying exactly in a line, as if they had been thrown up from a large fissure or rent extending across the Island, which had a communication with the interior.

Lancerote has been visited with several formidable eruptions, especially one which continued at intervals from 1730 to 1736, so severe as to drive away the inhabitants entirely; and another in 1824, in which a new volcanic mountain was formed by the stones ejected.

Madeira is composed in great measure of the same materials as the foregoing Islands, but no vestiges of any recent volcanic operations are discoverable; and the same remark applies to Porto Santo, which consists of an alternation of the above rocks with tertiary limestones, and sandstones disposed horizontally.

Mount Atlas.

Certain parts of Mount Atlas on the Continent of Africa, opposite to the Islands just alluded to, are said likewise to be volcanic.

The mountain called Black Harusch consists, according to Humboldt, of basaltic rocks of a grotesque form. Its Western range, called the Mountain of Soudan, has been explored by Ritchie, who describes it as formed by masses of basalt, which have burst through tertiary limestone containing fossil fish, as in the Vicentin. It was the Mons Ater of Pliny, and if any reliance is placed on the accounts of volcanic appearances reported to have been seen by Hanno whilst circumnavigating that part of Africa, it is more likely, that he should have referred to these mountains, than to the volcanos of Teneriffe, which were too distant from the coast for him to have touched upon.

Azores.

The last group of Islands in any degree connected with this portion of the Globe is that of the Azores, and this also is altogether of a volcanic nature. The Island of St. Michael, the largest of them, contains several conical hills of trachyte, some of them with craters, and covered by the pumice and obsidian they had ejected. This trachyte has, however, been protruded through strata of basalt and tuff, which constitute the fundamental rocks.

El Pico, the summit of which is 9000 feet above the sea, consists of a conical mass of trachyte, from which smoke is constantly issuing. In 1812, an eruption took place from the Island of St. George contiguous, which was probably connected with this same volcano, considered the only active one in the whole group.

In 1811 a phenomenon occurred near this group of Islands, similar to that already described as having taken place near Sicily, and in the Grecian Archipelago.

After a succession of earthquakes, experienced more or less sensibly in all the neighbouring parts, a new Island rose in the midst of the sea, of a conical form, and with a crater on its summit, from which flame and smoke continually issued. The Island, when visited soon after its appearance by the crew of the British frigate Sabrina, was about a mile in circumference, and 200 or 300 feet above the level of the Ocean.

Like the Island of Sciacca, however, it sunk again into the sea, after continuing to be visible above the waters for some weeks.

On the Volcanos of America.

Antilles.

All the smaller Islands constituting the West-Indian Archipelago, are composed either of coralline limestone of very recent formation, or of volcanic materials.

Those which consist wholly of the former, are of extremely low elevation, whilst the volcanic Islands rise often to a considerable height. The latter group may be divided into those which are entirely volcanic, and those which contain an intermixture of calcareous rocks.

The first of these classes comprises the following.

1. Grenada, in which there is an extinct crater filled with water.
2. St. Vincent, the site of an active volcano called *Le Souffrier*, which had a tremendous eruption in 1812.
3. St. Lucia, which also contains a very active volcano.
4. Dominica, the site of an extinct volcano.
5. Montserrat, of a solfatara.
6. Nevis, of the same.
7. St. Christopher's, of ditto.
8. St. Eustachia, of an extinct volcano.

The second division would comprehend,

1. Martinique, which consists chiefly of felspathic lava, constituting its three peaks, but which has calcareous rocks resting upon these volcanic materials.
2. Guadaloupe, one portion of which consists of coralline limestone, the other of volcanic rocks, containing fourteen craters, one of which is in an active condition, and had an eruption in 1797.
3. Antigua, in which calcareous rocks of recent origin predominate.
4. St. Barthelemi.
5. St. Martin.
6. St. Thomas, of which we possess no precise information.

It may be observed, that all those Islands which exhibit traces of the recent action of fire, are situated in a line on the Western boundary of the range, from North latitude 12° to 18°, and West longitude 61° to 63°.

Whatever indications of the kind occur further to the West, belong to eruptions of an older date.

Thus the volcanic islands of the Antilles seem to be the links, which connect the chain of primary mountains in the Caraccas, with that which runs across the Islands of Porto Rico, St. Domingo, Jamaica, and Cuba, both which lie nearly at right angles to that of the volcanic Islands enumerated. Yet the connection between the two is evinced, from the earthquakes, to which the non-volcanic chains above mentioned are so subject, ceasing, upon the breaking out of an eruption in one of the volcanos of the neighbouring Islands.

On the Continent of North America we meet with no recent volcanos further North than California, where three are stated as being at present in activity, although little is actually known concerning them.

Mexico.

In Mexico, traces of volcanic action belonging to every Age are strikingly manifest. Basaltic rocks and other modifications of pyroxenic lavas are met with in abundance, but the most elevated parts are composed of trachyte, which appears to have burst through the primary rocks, constituting conical or pointed mountains of enormous height. There would even seem to be a passage from these into granite, through the medium of a species of porphyry, which, though it partakes of the same ingredients as trachyte, is of a compacter texture, and which seems at the same time to be interstratified with the primitive rocks of the country.

But Mexico also presents a chain of active or half-extinguished volcanos, ranging in a linear direction across the Continent, and consequently at right angles to the primary chain above mentioned, which runs North and South.

In the parallel of the City of Mexico occur no less than five burning mountains, placed so much in the same line, that they appear to be derived from a fissure traversing Mexico from West to East; and it is interesting to remark, that if the same parallel line which connects these volcanos be extended in a Western direction, it would traverse the group in the Pacific called the Isles of Rivillagigedo, which there is reason to believe are also volcanic. See plate vi. fig. 3.

The most Eastern of these, that of Tuxtla, is situated a few miles to the North-West of Vera Cruz. In the same Province, but further to the West, occur the volcano of Orizaba, the height of which is 17,300 feet, and the peak of Popocatepetl 300 feet higher, the loftiest eminence in New Spain; whilst on the West of the City of Mexico are the two remaining ones, Colima and Jorullo. The elevation of the former is about 9000 feet. That of the latter much less considerable. It is remarkable, however, as affording us an instance of the breaking out of a volcano in a new spot; for the origin of this mountain dates no further back than the year 1759, when it was suddenly thrown up, with five smaller conical masses, from the midst of the plain called the Malpays, which also, over an area of three or four square miles, was upheaved with an inclination increasing from the circumference to the centre, the former being only thirty-nine feet above the old level, the latter no less than 524 feet. (See plate iv. fig. 1 and 2.)

Thousands of small cones from six to one hundred feet in height, called by the Indians Hornitos, or Ovens, are scattered over this upraised plain; they consist of clay intermixed with decomposed basalt, and are continually giving out steam.

Jorullo, at the time Humboldt visited it, was still emitting smoke, and had thrown out from its North side an immense quantity of scoriform and basaltic lavas. The surface of the Malpays was also still hot, and two streams of water, which were swallowed up in the hollow caused by the upheaved strata, reappeared on the other side of the plain, as warm springs.

In this brief account of the curious and instructive phenomena of Jorullo, we have taken for our guide, Humboldt, as the only scientific traveller who has given us an account of it, after an actual inspection of the spot. We are aware, indeed, that doubts have been thrown upon his explanation by certain English Geologists, who are reluctant to admit the fact, of upheavings having taken place amongst volcanic materials; but without entering into this question at present, we may remark, that those who admit the uplifting of a whole Island at once from the bed of the Ocean, (and who, that is conversant with volcanic phenomena, can question that such events have occurred?) need feel no difficulty in admitting the testimony of the Indians, or the opinion of Humboldt, with respect to the fact of a mountain like Jorullo having been uplifted bodily from the interior of the Earth.

The active volcanos above enumerated are connected, one with the other, by several which are extinct; thus between Orizaba and Popocatepetl, lies the Coffie de Perote, and between Popocatepetl and Jorullo, the extinct volcano of Mexico, otherwise called Iztaccihuatl, whilst Colima, as we have seen, lies between Jorullo and the Islands of Rivillagigedo above noticed as volcanic.

In the new Republics of Guatimala and Nicaragua, a line of volcanos occurs lying parallel, instead of transversely, to the chain of the Cordilleras. Between North latitude 10° and 15°, twenty-one active vents are enumerated. South of the Isthmus of Darien, in the Republic of Columbia, no less than thirteen occur.

One of these, the Peak of Tolima, is in the department of Cundinamarca, and the Province of Bogota, forty leagues from the coast, and amongst the central Andes. Seven are in the department of Cauca, which extends along the coast of the Pacific; four of them belong to the group of Popayan, and three to that of Pastos, two Provinces comprehended in that department; whilst further South, in the Province of Pichinca, or Quito, belonging to the department of the Equator, are five active volcanos.

The connection between these last, and the volcanos of the department first mentioned, was evinced in 1797 by the following circumstance.

A dense column of smoke had for some months been observed to issue from the volcano of Pasto in the latter Province, which all at once disappeared; and it was afterwards found, that at this exact time the town of Riobomba, sixty-five leagues further South in the Province of Pichinca, which lay contiguous to the volcano of Tunguragua, was destroyed by a fearful earthquake.

It is remarkable that the whole of this line of volcanos lies Westward of the Andes. To the East of this chain exist, indeed, three small vents near the sources of the River Caqueto, Napo, and Morena; but these, according to Humboldt, probably result from the lateral action of those of Popayan and Pasto, whilst Buenos Ayres, Brazil, Guayana, and Venezuela are altogether destitute of these phenomena.

South America.

On the Western side of the Cordilleras, however, the line of volcanic operations would seem to extend uninterruptedly along the whole coast to Chili; for although in the interval of 30 degrees that occurs between the latter Republic and Quito only one burning mountain exists, that of Arequipa in Peru, yet it seems probable, from the frequent earthquakes that agitate the intermediate tract, that the same processes are going on beneath, although no permanent vent exist for the discharge of elastic vapours.

In Chili, sixteen active volcanos are enumerated, of which two only exist on the coast, the rest being situated in the midst of the range of mountains, which runs in a direction nearly parallel to it, but further inland. Thus we may trace a line of volcanic operations along the greater part at least of the Western coast of South America, the loftiest eminences being of trachyte, which encircles in zones a large portion of the table land, but rarely extends into the valleys, forming conical mountains, which often serve as vents for the aeriform or solid materials elaborated below, but at other times are unaccompanied with lava streams or scoriæ, and apparently have no vestige of any crater.

The latter appears to be the case with Chimborazo, the highest point of the New World, whilst Cotopaxi, the next in point of elevation, has given birth to frequent and violent eruptions

SECTION 2.

Other Phenomena referable to volcanic action.

We have now completed our proposed sketch of the distribution of those volcanos, which either are in activity at the present time, or, if dormant, have at least left such evident traces of their former existence, in the rocks which they have ejected, or the lava currents which they have poured forth, that we cannot hesitate in regarding their operations, as being of the same nature, and brought about under the same external circumstances, as those of which we are eye-witnesses.

Wide indeed as may be the interval, in an historical sense, between certain of these, as, for instance, between the latest eruption even of the volcanos of Auvergne, and the earliest recorded one of Vesuvius; yet the whole together constitutes the same Geological epoch, one in which the general features of the country were nearly as at present, the climate not materially different, and the races of animals those which are now existing.

And although the earlier volcanic rocks, found in these Countries, were produced at a period to which these remarks do not apply, one in which large fresh-water, and in some instances salt-water, lakes occupied what is now dry land, when the climate was warmer, and the animals in many cases such as now no longer live in any part of the Globe; yet are these so connected in character and position with the more modern products of volcanos alluded to, that we need not hesitate, either to refer them to the same cause, or to comprehend them in our enumeration.

The case of the trap rocks is somewhat different; for though few at present contend that they are of aqueous origin, all must admit, that if produced by volcanic action, it has been by operations differing in some respects from those at present taking place, either in their own nature, or in the external circumstances which influenced them; so that in laying the foundation for a series of deductions with respect to the nature and effects of subterranean fire, where it may be best to throw aside every thing of an hypothetical character, and to consider only that which is incontestably volcanic, we should do wrong in taking into the account these igneous productions of an earlier Age.

Nevertheless there are certain other phenomena which must be contemplated, if we wish to estimate the amount of volcanic action in all its different phases.

Earthquakes.

The first of these is earthquakes, which may be proved on tolerably secure grounds to have, in all cases, a connection more or less intimate with volcanic agency, and ought therefore to be regarded as one of the modes, in which these forces manifest their existence over the Earth's surface at the present day.

In some instances, indeed, earthquakes have occurred so immediately antecedent upon volcanic eruptions, and are so manifestly derived from the same centre of action, that no better proof could be offered to establish an identity of origin.

In other cases, the evidence, though not quite so direct, is perhaps as cogent as need be required, in order to substantiate the point in question. When, for instance, we observe two volcanic districts, both subject to earthquakes, which are ascertained, by their coincidence in time and other circumstances, to have a connection with the volcanic action there going on, and find that an intermediate country, in which there are no traces of the operation of fire, is agitated by subterraneous convulsions, similar in kind, but stronger in degree, than those occurring in the immediate vicinity of the volcanos; have we not reason to conclude, that the same action extends throughout the whole of the above area, and that it is this which produces in the intermediate space the effects alluded to, which are often the more violent from the absence of any natural outlet, whence the elastic vapours set in motion, which immediately suggest themselves to us as the cause of the convulsions experienced, could find a channel of escape?

Now, in proof of the former of these positions, it may be scarcely necessary to do more than to appeal to the case of Etna and Vesuvius, which rarely return to a state of activity after an interval of repose, without some antecedent earthquake, the latter usually ceasing, so soon as the volcano has once established for itself a vent, whereby these elastic vapours can discharge themselves. Such was the case before the celebrated eruption of A. D. 79, in Campania, as well as in that of Etna in 1537, when, says Fazzello, noises were heard and shocks experienced over the most distant parts of Sicily. In such cases, no one would pretend to doubt the connection between the volcano and the earthquake.

The second point seems established, by considering the tremendous earthquakes which ravage so often Campania, and those mentioned by Humboldt as intervening between and in the line of the volcanos, of Columbia, Quito, and Chili. Von Buch has shown, in his paper on Lanzerote, the comparative immunity enjoyed by Teneriffe from those convulsions of Nature, which agitate the neighbouring Islands, destitute of that great chimney or safety-valve afforded it by the Peak of Teyde.

But before we are entitled to appeal to earthquakes, as affording an independent source of evidence with respect to the existence of volcanic action, it will be necessary to show, that no other natural cause is likely to

have produced such effects, more especially as even those who admit their volcanic origin in the above cases, have, nevertheless, been disposed to assign to them a different origin in others. Such a distinction seems to be hinted at by Werner, who acknowledged two classes of earthquakes: the first connected with a particular volcano, and felt only within a radius of some miles from it, and at a period when the latter was in a state of activity; the latter less manifestly related to any such cause, being spread over a much larger tract of country, and, therefore, as he conceived, situated at a much greater depth.

Their Phenomena.

This renders it necessary for us to pass in review the phenomena most commonly attendant upon earthquakes, in order to ascertain, how far they appear to countenance the supposition, that other causes, besides those of a volcanic nature, might have contributed to produce them.

It would greatly confirm such an opinion, if it could be shown, that there were any phenomena common in one class of volcanos, which were absent from, or uncommon in, the other; but as no one has attempted to make such a distinction, all that remains to be done is to consider generally the concomitants or sequelæ of earthquakes, with a view of ascertaining, how far they are reconcilable to any other than a volcanic cause.

None of these, indeed, can be considered as universal: thus in some earthquakes the shock consists in an horizontal wavy motion; in others in an upward heaving; and in a third class in a vibration backwards and forwards.

There is usually a sort of subterranean noise attending them, which has been compared to thunder, or the rolling of artillery, but this is not constantly present; and on the other hand the noise has been heard without any concomitant earthquake. A peculiar smell of a sulphureous nature has been occasionally experienced, and other phenomena, such as the bursting out of flames from the earth, the overflowing of wells, the ejection of water from fissures formed at the time, are noted in particular cases.

The following may be enumerated as the meteorological phenomena usually coincident with earthquakes.

Irregularities in the season preceding or following the shocks, sudden gusts of wind interrupted by dead calms, violent rains at period, where such phenomena are unusual or unknown in the country; a reddening of the Sun's disk, and a haziness in the air often continued for months; an evolution of electric matter from the ground, together with indications of some extraordinary condition of the atmosphere, evinced both by the inferior animals and by man, the former uttering cries of distress, and evincing extraordinary alarm, the latter experiencing a sensation like sea-sickness or dizziness in the head. These phenomena, however, appear to be equally common during the continuance of volcanic eruptions, as of earthquakes, and indicate in both cases the tendency of any great subterranean movement, proceeding from whatever cause, to disturb the equilibrium of the atmosphere.

The only other hypotheses, by which earthquakes have been accounted for, are, that of Stukeley, who refers them to subterranean discharges of electricity, and that of Buffon, who attributes them to the falling in of caverns existing in the interior of the Globe.

The arguments that have been from time to time advanced in favour of the electrical theory are vague and inconclusive; they are drawn from some fanciful analogies between the noise and shock accompanying lightning, and those which are experienced during an earthquake; from the extreme rapidity with which the motion is propagated, to which the passage of electricity alone is comparable; from the electrical state of the atmosphere both before and after an earthquake; and from the sulphureous smell sometimes perceived, which is thought to resemble that produced by the electrical spark.

No one, however, has yet attempted to show, that any of the above phenomena are limited to those earthquakes which they are disposed to *separate* from volcanos, neither do they appear by any means incompatible with this view of their nature and origin.

Electrical phenomena are indeed equally common during the continuance of volcanic eruptions, produced in all probability by the evolution of large quantities of steam and other elastic fluids, the decomposition and subsequent regeneration of water, and other processes which accompany these great operations of Nature.

The late discoveries, indeed, which have been made with regard to the opposite electrical condition of mineral veins and the rocks containing them, may lead us to believe, that much remains to be learned with regard to the agency of this mysterious power in the interior of the Earth; yet we can hardly believe, that in the solid strata of the Globe, consisting, as they do, of conductors, the same accumulation of electricity can ever occur, as that which produces the phenomena of thunder and lightning in the atmosphere.

With regard to the theory of Buffon, it may be sufficient to observe, that the existence of cavities in rocks can only be supposed to arise from two causes; something connected, either with their original formation, as in the case of limestones, or with the convulsions that have subsequently affected them.

Now with regard to the *first*, it is highly improbable, that any great spontaneous sinking of hollows, that have existed for so long a period, should take place in the present day; and with respect to the second, the very existence of *such* hollows implies the previous exertion of volcanic agency, for we know of no other cause in nature, competent to heave up rocks in the manner necessary to produce such cavities.

Besides, although the sudden falling in of a cavity might produce a shock extending over a considerable area, yet there is no reason, why it should spread in one direction more than in another.

In truth, however, the chief difficulty, which prevented our predecessors from acting in this instance on the sound maxim in philosophy, of not assuming more causes for natural effects than were necessary for explaining the phenomena, has been removed by the progress of modern discovery, which, by increasing our knowledge of volcanos, has convinced us, that whilst their manifest distribution is far more extended than we had once supposed, the probable indications of their former agency are to be met with, in almost every part of the Globe where earthquakes have been experienced.

This, of course, renders it more easy to refer earthquakes in general to some focus or other of volcanic operations; especially if we assume, what in itself is highly probable, that the eruptions of burning mountains are only the extreme manifestations of a cause generally diffused throughout Nature, and that the minor

indications of the same may therefore be looked for, where these mightier ones are unknown.

It has, indeed, been sometimes alleged, that from the wide extent over which the shock of an earthquake is sometimes diffused, the immediate seat of the action must be at a depth incalculably greater, than that which we are disposed to assign, either to volcanos, or any other natural force; and Dr. Stukeley has undertaken to overthrow the volcanic hypothesis by a sort of *reductio ad absurdum* derived from a calculation of this kind; showing, that as the earthquake which occurred in Asia Minor in A. D. 17 extended over a diameter of 300 miles, it must have proceeded from a point 200 miles beneath the surface. The superficial extent, however, of earthquakes need not create a difficulty in the present day, when we are aware of the vast distances to which sound and other vibratory motions may be propagated along the substance of solid bodies, and are therefore at liberty to consider the minor effects of an earthquake, to be merely the undulations of the principal shock, propagated laterally through the strata of the Earth.

Gay Lussac observes, that the shock produced by the head of a pin at one of the ends of a long beam is distinctly transmitted to the other extremity, and thence infers the vast distances, to which that communicated by elastic vapours, suddenly generated, and struggling for escape, might be expected to extend.

This consideration, whilst it renders us cautious as to inferring the existence of volcanic action in every spot where earthquakes are experienced, will enable us to reconcile their phenomena with the more moderate depth, which we are induced from other reasons to assign to volcanos themselves.

Upon the whole, then, we are disposed to regard earthquakes as exclusively of volcanic origin, and consequently to appeal to them, as indicating, in the parts where they manifest themselves in their greatest intensity, the operation of subterranean fire, regarding the minor shocks as mere undulations of the strata, occasioned by the primary impulse communicated.

Thermal Waters.

Another class of phenomena, which, like earthquakes, are manifestly connected with volcanos in some instances, but may appear of doubtful origin in others, are hot springs; but we confidently expect, that a brief review of the nature of their contents, of the situations in which they are found, and of other circumstances belonging to them, will lead to the same conclusion, to which we arrived in the former instance.

The solid contents of thermal waters, being obviously derived in most instances from the rocks through which they have percolated, afford little either to confirm or to refute this opinion; but the gases which accompany them are plainly to be traced to the immediate source of the heat, and are given off by the processes to which the latter must be referred.

The Gases given out by them.

Now if it should appear, that the same aeriform fluids are evolved from hot springs, which appear to be emitted by volcanos, a presumption will arise highly favourable to an identity in their respective origins, which will obtain a greater degree of force, in proportion as the gases are generated less commonly by other natural processes.

Thus sulphuretted hydrogen is an ordinary accompaniment both of volcanos and of thermal waters; but the argument drawn from its presence is weak, because the same gas often occurs in springs possessing only the medium temperature, as the effect of processes totally unconnected with volcanic operations.

The same remark applies to the carbonic acid so frequently present in springs, in a proportion exceeding that in which it would be imparted to them by the atmosphere.

Its frequent connection with volcanos is unquestionable, for there are scarcely any, that do not evolve it, either alone, or through the medium of the springs contiguous; but as any cause, which was adequate to impart heat to the water, might equally produce an evolution of carbonic acid from calcareous and other rocks which contained this ingredient, the proof in the above instance is not stronger than it would be without it.

But there is a third description of air evolved from springs, the presence of which seems better calculated to establish their connection with volcanos, since, unlike the first, it is disengaged in a state of purity by no other known process going on in the interior of the Globe, and unlike the latter, cannot be accounted for, in many instances at least, by the mere action of heat on any of the constituents of the surrounding rock formations.

The gas alluded to is nitrogen, which was detected by Sir H. Davy in the white vapour given off by Vesuvius after its eruption in 1819, mixed with only half its usual quantity of oxygen, and by his brother Dr. John Davy in one sample of gas which he collected near the new volcanic Island off Sicily. Its existence, however, in volcanos is more fully substantiated by the ammoniacal salts copiously evolved by many of them; and it is given off from springs, which so manifestly derive their temperature from their contiguity to the latter, that we can scarcely help placing this gas amongst the commonest products of volcanos, during the more languid conditions of their action. Thus it has been observed by a recent chemist, proceeding in large quantities from a spring at Castellamare, in the Bay of Naples; by Professor Daubeny, mixed with a predominant portion of carbonic acid, in the hot springs of Mont Dor and Bourboule in Auvergne, and in those of Chaudesaigues in Cantal; and by M. Longchamp at Vichy: all places, be it observed, so connected with the extinct volcanos of Auvergne, that the heat of the springs must, in these instances at least, be referred to a volcanic source.

Now the gas evolved from the thermal waters of the Alps, however distant they may be from volcanos in action during the present condition of the surface, seems to be generally of the same description; the carbonic acid, which may probably have accompanied it, being in these cases absorbed by the water through which it had to pass.

Thus Professor Daubeny discovered it on the Savoy side of that chain, issuing in large quantities from the spring of St. Gervais; and on the Italian side, from those of Sainte Marguerite at Cormayeur, of St. Didier in the same valley, and of Bonneval in the Tarantaise, half-way between the Bourg St. Maurice and the Col de Bonhomme. In only one of these springs did carbonic acid appear to be present, and in this case it amounted to about 12 per cent. of the whole quantity emitted.

Dr. Ure also mentions his having detected azote issuing in a state of purity from the baths of Loueche in

Swisserland. In this Country, the same gas has long ago been detected in the thermal waters of Bath and Buxton; and more recently it has been found by Professor Daubeny in those of Bakewell and Stoney Middleton in Derbyshire, and that of Taafe's Well in South Wales.

In other portions of the Globe the same gas has been noticed in the thermal waters there met with. Thus Dr. Davy detected it in a state of absolute purity issuing from certain warm springs near Trincomalee in Ceylon, and Boussingault and Rivero in certain ones occurring in the primitive chain of the Cordilleras in Venezuela. (*Annales de Chimie*, vol. xxiii.) It is remarkable, however, that M. Boussingault has since examined certain hot springs in immediate connection with the volcanos of Equinoctial America, and finds them to give out no azote.

The quantity of this gas emitted in a given time is often very remarkable; but the only attempt to obtain a correct estimate of its amount, with which we are acquainted, is that by Professor Daubeny, with respect to the thermal waters of Bath, detailed in a Memoir read before the Royal Society in December, 1833.

It appears, from an average of twenty-four observations made on different days of September and October in that year, that the quantity of gas emitted per minute from the King's bath alone was 267 cubic inches, or about 222 cubic feet in the twenty-four hours. This consisted of about 97 per cent. of nitrogen, and 3 per cent. of oxygen. There was also found a quantity of carbonic acid, varying from $4\frac{1}{2}$ to 13 per cent.

The quantity of gas emitted differed a little from day to day, but the variation did not appear to depend upon the state of the barometer or other atmospheric changes.

Thermal Waters.—Their Situation.

The situation of many hot springs tends also strongly to confirm their relation to earthquakes and other physical convulsions, thus connecting them with the same series of natural phenomena.

Where not placed in the vicinity of active or extinct volcanos, (which is the case with the greater number,) some evidence of violence, some rending or dislocation of the contiguous rocks, may often be perceived. Thus they abound near the base of certain chains of mountains, which, in their highly inclined strata, give evidence of having been heaved upwards, but are comparatively rare in the low country, at a distance from those great centres of elevation, where the nature and position of the rocks indicate no changes, excepting those which may have been brought about, either by the sudden and violent, or the slow and continued, action of water.

If, as in England, thermal waters also occur at a distance from any of the great systems of elevation alluded to, it will generally be found, that the spots themselves exhibit proofs of violent, though more local, convulsions having, at some period or other, taken place in their vicinity.

For instances of this kind, derived from other Countries, we may refer to Professor Daubeny's *Memoir on Thermal Waters*;* on the present occasion, want of space compels us to confine ourselves, to one or two facts drawn from the Geology of England.

Thus the defile, from which issues the tepid spring of St. Vincent's Rocks, near Clifton, is considered by the best observers as the result of some internal derangement of the strata, brought about by disturbing causes of great antiquity; and in like manner, the similar gorge at Matlock, out of which its tepid springs issue, is associated with a great dislocation of the strata, attributable to their having been tilted upwards at an high angle to the West.*

The same fault has been traced by Mr. Farey as far as Buxton, and from thence to the villages of North Bradwell and Stoney Middleton, in all which places have been noticed springs, possessing a temperature more or less elevated above the medium point of that climate.

We must not, indeed, expect to meet with the same direct evidence, in the case of every hot spring that comes under our examination. At Bath, we know of no dislocations in the strata posterior to the age of the coal and mountain limestone, and it would, perhaps, be rash to connect these with the cause of the thermal waters there existing. Nevertheless, when we consider, in how very large a proportion of cases some indication of an igneous character may be traced, the absence of proof in the few remaining ones may, perhaps, be fairly referred to the imperfection of our knowledge.

The volcanic nature of thermal waters is likewise confirmed, by the relation which seems to subsist in general between the elevation of their temperature, and the date, which we should be induced from other considerations to assign, to the latest manifestations of volcanic agency in the country.

Thus, those which make the *nearest approach* to the boiling point of water, are uniformly found amongst volcanos now in action; next in the order of temperature are those associated with volcanos, which, though now extinct, appear to have existed at a period, Geologically speaking, recent, that is, at a time when the great features of the country were nearly as at present; whilst the springs, which gush out at the foot, or in the midst, of uplifted chains of mountains, at a distance from those rocks which are generally regarded as volcanic, never possess a temperature so elevated, as the two preceding classes of thermal waters sometimes attain to.

Now, if these latter were really produced by other causes than volcanos, it does not seem intelligible, why they should, in all cases, observe that lower degree of heat, which indicates, either a cause of less intensity, or one whose effects have been moderated by a longer intervening space of time.

Lastly, the other solutions of the heat of springs appear on examination totally inadequate to account for their phenomena. In the case of the Bath waters, indeed, the warmth has been attributed to the decomposition of pyrites, in which the lias clay, from whence it issues, abounds; but to this it may be objected, that the same stratum, though equally charged throughout with this mineral, nowhere else throws out springs possessing more than the medium temperature; and yet, the sulphuretted hydrogen, which the latter so frequently contain, shows a decomposition of pyrites to be going on in several other places. Besides, it is remarkable, that thermal waters, far from being impregnated with those saline ingredients, which would naturally enter into

* *Edinburgh New Philosophical Journal*, Oct. 1831.

* A striking instance of the same kind, taken from the Pyrenees, is exhibited in pl. v. fig. 8. at a place called St. Paul de Fenouilhades, Dep. des Pyrénées Orientales. We there see a thermal spring gush out from a narrow gorge in an elsewhere continuous line of hills, the strata of which lose their horizontality and sink abruptly on both sides towards the fissure.

their constitution, if they were caused by the heat generated in consequence of such chemical processes taking place in the interior of the Earth, are, on the contrary, in the great majority of instances, remarkably free from foreign matter. Thus the Bath waters contain not a particle of the sulphuretted hydrogen, or sulphate of iron, which would have arisen from the decomposition of pyrites; and the mineral contents of those connected with primitive chains, such as the Alps or Pyrenees, although obviously referable to the action of water, assisted by heat and pressure, upon felspathic rocks, are far from suggesting any distinct chemical operation, by which this heat could have been elicited.

Upon the whole, without pretending, that the evidence in the case of thermal waters is so conclusive as in that of earthquakes, or denying, that there may be instances, in which springs have acquired an extraordinary temperature from local causes of a different kind, we hold, that their existence affords a strong indication of subterranean processes similar to those, which, on a more extended scale, gave rise to earthquakes, especially wherever we observe such a continuous and connected range of them to occur, as that which we find encircling the base of particular chains of primitive mountains, or associated with certain leading systems of elevation.

Evolution of Carbonic Acid.

There is yet another natural phenomenon closely connected with the subject of thermal waters, which remains to be considered—we mean the evolution of carbonic acid from the interior of the Earth, either alone, or accompanying certain springs.

The relation of this to volcanic processes may be established by a similar line of argument to that we have pursued in the former instance, namely, by pointing out its frequent occurrence, in conjunction with thermal waters, and in situations which have undergone certain physical convulsions.

Thus the same country, which throws out warm springs at a low level, and at a point more contiguous to the supposed focus of the volcanic action, affords cold carbonated ones at a higher level, or at a point more remote. The hot springs of Ems and Wiesbaden, for instance, are found near the base of the Taunus mountains, whilst the cold effervescing ones of Schwalbach and Fachingen occur higher up in the same chain; thus, too, the same district which gives rise to the thermal waters of Aix la Chapelle, furnishes the chalybeates of Spa near the summit of the hills above. The connection of carbonated springs with faults may be observed in Derbyshire and Yorkshire, but it has been more satisfactorily traced in Germany, where they have been found to issue from what have been termed circular valleys of elevation; that is to say, valleys which are, or appear at one time to have been, enclosed by escarpments, the strata dipping away in all directions from the centre towards the circumference. Several valleys in Westphalia exhibit this remarkable structure, and none more strikingly than that, in which the cold chalybeate of Pyrmont is situated. In this instance the rocks are composed of the variegated sandstone, the muschelkalk limestone, and the keuper, which are seen overlapping in the hills bounding the valley, but dipping in opposite directions on opposite sides of it, so as to present every where escarpments fronting each other. (See pl. v. fig. 7.) From the bottom of the valley carbonic acid is constantly issuing in large quantities, impregnating the springs of water, and accumulating in dry pits and caverns. The valley of Dryburg, and other spots in the same country, noted for the occurrence of cold carbonated springs, exhibit a similar conformation in their strata.

Rullman, in his description of Wiesbaden, remarks, that in the neighbourhood of the carbonated springs which so abound in the Duchy of Nassau, the rocks are subject to remarkable changes in their dips, to saddle-shaped stratification, and to fractures. The character of the rock is also frequently more friable near the mineral springs.

Professor Buckland, in his *Memoir on Valleys of Elevation*, published in the *Transactions of the Geological Society*, had previously pointed out the occurrence of such valleys in England; and it may be worth remarking, though as an isolated fact, perhaps, not of much weight, that the most important of our chalybeates, that of Tunbridge, is found in this kind of situation.

Now the relative position of the strata in these valleys just as obviously suggests the idea of their having been affected by some convulsion of Nature, as the highly inclined rocks of Alpine Countries; and it is impossible to conceive, either that they could have been deposited in the first instance at so high an angle, and with such a variety of dips, or that there should have been such a coincidence between the elevation of their escarpments on the opposite sides of the valley, if the beds had not once been in continuity.

It may be inquired, whether even those accumulations of carbonic acid, which take place so frequently in neglected mines and wells, and which have imposed the necessary precaution of letting down a light before we venture to descend into them, may not be owing to a slow evolution of this gas from fissures beneath, in which case a volcanic action may be assigned, as, at least, its most probable cause; the law of the rapid diffusion of all gases through the atmosphere precludes the possibility of attributing it to a mere separation of carbonic acid, in consequence of its greater specific gravity, from the other constituents of the atmosphere; and the same cause would quickly dissipate it, even if it were given out by the decomposition of organic matters.

Nevertheless, before we allow ourselves to adopt this opinion, it will be necessary to ascertain, first, whether in these cases any local causes for the production of carbonic acid exist; and, secondly, whether its further generation might, in these cases, be prevented by covering the bottom and sides of the pit with some coating impermeable to air.

Mud Volcanos or Salses.

With regard to those emanations of gas and vapour, which occur in certain Countries, accompanied with eruptions of mud and petroleum, we must withhold our assent to the vulgar opinion, which attributes them to volcanic action, as the name of mud volcanos, by which they are usually designated, seems to imply.

That they are often connected with them, we are not, indeed, disposed to deny, but they appear to be so only in the relation of an effect, produced by the presence of inflammable materials, brought together by the operations of some pre-existing volcano.

That the process itself is distinct from that which takes place in the latter, is evident, from considering that

in every case in which it has been examined, the seat of the action is found to be quite superficial, and to reside in a stratum of very recent origin, known to be strongly impregnated with sulphur and petroleum. Such is the case at Macaluba near Girgenti, in Sicily, where the mud volcanos, as they are called, lie quite detached from the true volcanic phenomena of Etna or of the Val di Noto, and seem manifestly dependent on the combustion of the sulphur, which exists in the rock in such quantities as to supply all Europe with that material.

The same is likewise the case with the "Salses," or mud volcanos of Modena, which lie at a distance from every genuine burning mountain; and, according to Humboldt, with those of New Andalusia and the Island of Trinidad. The phenomena exhibited by those in Sicily, and amongst the Subapennine Hills, are in general of a very insignificant kind, consisting of a mere evolution of water mixed with mud and bitumen in consequence of the disengagement of gas, apparently consisting of carbonic acid and carburetted hydrogen, from little circular orifices on the summit of the hill. Ordinarily, nothing but a bubbling up of gas from the interior of these craters is to be observed; but it is said, that there are times, at which the process has been known to go on with considerable energy, for the mud has been thrown up in Sicily to the height of 200 feet, accompanied with a strong odour of sulphur.

In the little Island of Taman, which connects the chain of mountains traversing the Peninsula of Crimea with the Asiatic Continent, the process in question seems to be proceeding on a more extensive scale. Pallas represents occasional eruptions as taking place from certain crevices in the rocks of this Island, which began with a thick smoke, followed by a column of flame fifty feet in height, which continued in one instance for eight hours and a half incessantly, during which time streams of mud flowed in all directions, but no lava or altered masses of stone were ejected. The accounts given by Mr. Heber, in his Manuscript Journal attached to Dr. Clarke's *Travels*, fully confirm this view, and render it highly probable, that the phenomenon is altogether analogous to that of Macaluba in Sicily, and of the Salses near Modena.

Assuming, therefore, these latter as the best types we possess of mud volcanos, and reasoning from them to the rest, it will probably appear, that all the phenomena they exhibit will admit of explanation from the mutual action of certain substances, originally accumulated in submarine solfataras by antecedent volcanic processes, the result of which would be the extrication of carbonic acid, and of an inflammable gas arising from the slow distillation of bituminous matters, together with the rise of water, through the channels originally established by the gases discharging themselves upwards. That volcanic action is not necessarily the cause, is shown by finding a similar phenomenon described as occurring in the Western States of Ohio, where it seems quite unconnected with any such cause.

In this spot the salt springs, which so abound, are found to be constantly giving rise to an evolution of carburetted hydrogen gas, accompanied with much petroleum. The jets of gas are sometimes so forcible, as to throw the water entirely out of the spring.

There seems, therefore, no necessary connection between such phenomena and our present subject, and their more frequent occurrence in rocks which lie in the neighbourhood of volcanos may be readily accounted for, by the tendency of the latter to bring together materials proper for carrying on such operations.

Emanations of Inflammable Gas.

Still less are we disposed to attribute to a volcanic cause the emanations of inflammable gas, which are occasionally seen issuing from the crevices of rocks, in a continued, and, according to our limited notions of time, an unfailing current.

The evolution of carburetted hydrogen from the cracks and crevices of coal mines, enables us to conceive, by what natural processes such a phenomenon may be accounted for, and the recent discoveries, with respect to the liquefaction of the gases, render the regular and lasting discharge of such a stream of elastic matter more intelligible. Now the phenomenon in question, when divested of the marvellous, reduces itself simply to this, for it is a mistake to imagine, that the flame is self-kindled, at least in the instances that have been well examined, although, when the gas is once set on fire, the supply is sufficiently regular to keep up a continued combustion.

The most noted instances of this phenomenon are at the Pietra Mala, on the summit of the Apennines, between Bologna and Florence; at a place called St. Barthelemi, near Grenoble;* and in the Chimariot mountains in Albania, where it is probable that it has continued for the last 2000 years, for many ancient writers speak of a Nympheum on the coast of modern Albania, near Apollonia, celebrated for the flames that rose continually from it, and Dodwell's authority establishes the existence of the same at the present day in that country.

It is probable, that the phenomena which occur at Baku on the Western side of the Caspian, where the soil is strongly impregnated with petroleum, are connected with these last-mentioned causes, rather than with those of genuine volcanos.

There is indeed a report given of an eruption, which took place in that Province in the year 1827, but from the description it would seem to amount to nothing more, than a combustion of bituminous matters on a larger scale than usual. It is said, that a vast column of fire rose to an extraordinary height, maintaining itself at the same for three hours, after which it gradually diminished to twenty inches; the fire extended itself over a tract of ground 1300 by 1900 feet in diameter. At the time of the first eruption red-hot stones and volumes of water were ejected. No appearance of a crater was to be perceived, but the spot, whence the column of flame rose, was elevated about two feet above the general level of the plain. The surrounding tract resembles a ploughed field, and is covered with a variety of anomalous products of heat. There are, however, no ejections of water, nor any of those sulphureous exhalations, which are commonly met with in such cases, as at Macaluba, and in the other so called mud volcanos.

Section 3.

Theories of Volcanic Operations considered.

The phenomena, therefore, to which we feel warranted in appealing, as indications of igneous action going on

* The writer of this Article visited this spot in 1830, and found that the flame rekindled when merely blown out, but that it could be extinguished by throwing water over it several successive times. The gas was collected and burnt, and water and carbonic acid were the results.

in the interior of the Globe, are those of volcanos, earthquakes, thermal waters, and emissions of carbonic acid gas; and in order to estimate the amount of the changes that may have been brought about on the crust of the Earth by their united operation, it will be necessary to inquire with respect to the probable cause of these internal commotions, as a clew not only to guide us concerning their present action, but likewise as to the probability of their more or less extended influence in periods that have gone by.

The theories which have been propounded, with the view of accounting for the existence of volcanic action, may be divided into two classes; those which assume some chemical process, of which the heat is merely an effect, and those which, assuming the existence of the heat, deduce the other phenomena from its presence.

In the former, in short, the heat is *one* of the effects; in the second, it is the cause of *all* the phenomena observed.

The theories, however, which belong to the former of these classes, though agreeing in this one particular, that of imagining combustion of some kind to have caused the heat, differ widely as to the material which excited it; coal, petroleum, and sulphur, having all at times been assumed as the main agent concerned in the process.

But these substances have been shown, not only to be in themselves totally inadequate to explain the phenomena, but to be productive, when set on fire, of a train of effects altogether different from those of genuine volcanos; witness those arising from the accidental burning of coal mines in many parts of Great Britain, of masses of petroleum, as at Baku, or of sulphur and bituminous matters, as at Macaluba.

Accordingly it is now generally admitted, that no processes going on near the surface are calculated to produce the phenomena of volcanos; and that if the latter arise from combustion, the materials which occasion it must, in part at least, be of a different description from the combustibles which exist in a natural state within the sphere of our observation, since in order to consume oxygen without substituting for it a corresponding amount of some gaseous oxide, the products must be of a fixed nature, which is not the case in our artificial fires.

Recent discoveries have, however, convinced us, that the whole of the crust of the Earth contains principles, which in their uncombined state are in a high degree inflammable, and which, for this very reason, never occur to us, except in union with oxygen. Such are the alkalies and earths, which Sir H. Davy has shown each to contain a metallic basis, a body capable of abstracting oxygen, both from common air and from water, and giving rise at the time to a sufficient extrication of light and heat, to constitute a case of genuine combustion. There must have been a time, therefore, when these substances existed uncombined with oxygen even on the surface, and there is no reason to deny, that the process of oxygenation may still be incomplete at those vast depths, when air and water are admitted but slowly, or at distant intervals.

There seems therefore no *à priori* absurdity in imagining, that volcanic action may consist in a process of oxygenation, caused, in part at least, by the presence of these substances, and all that seems necessary, is to ascertain, how far the known phenomena accord with such an hypothesis.

The other class of theories, which assumes the high temperature, and then deduces from it the phenomena, seems at first sight to have an advantage over the preceding one, inasmuch as the existence of an internal heat may be said to be in a manner ascertained, whilst that of the alkaline and earthy metalloids, uncombined with oxygen, is at most only probable; and accordingly many have been induced to prefer this mode of accounting for the phenomena, as less hypothetical and requiring fewer postulates.

They forget, however, that the existence of an internal heat is assumed alike on either supposition, and that the true point of dispute is, whether it can best be explained by the presence of a melted or ignited mass in the interior of the Globe, or by a process of oxygenation going on in its constituents.

Now the only distinct argument in favour of the internal fluidity of the Globe, is deduced from its figure, which has been proved to be that of an oblate spheroid; a form, it is contended, which could not have been imparted to it, had it not been originally in a liquid state, and from thence the advocates of the above hypothesis conceive themselves at liberty to infer that it is so at present.

Neither of these propositions, however, can be regarded as demonstrated. Sir J. F. Herschel has shown, in his *Treatise on Astronomy*, that the oblate figure of the Globe may only have arisen from its long continued rotation, this being the point to which, under this condition, it must tend, and which it would ultimately attain, even as its surface is at present constituted.

Neither, if we grant the Earth to have been originally fluid, is there any direct proof, that it must have continued so till the present time; for the increased temperature observed at the slight depths to which man has penetrated below the surface, only proves, that the temperature of the crust is higher than that of its superficies, not that it is considerable enough to retain the substances of which the interior is made up in a state of fusion.

The proper mode, however, of considering the question seems to be, not to lose ourselves in conjectures, as to what may by possibility be the condition of the Globe at inaccessible depths, but to pass in review the actual phenomena of volcanos, and see, whether we can best deduce them, from the mere effects of the protrusion of a melted mass of matter, or from a process of combustion, originating in materials which may still exist in an unoxidized state below.

In order, however, to determine this, it will be necessary to consider at some length, first, the geographical situation of volcanos; secondly, the character of the substances evolved by them in a gaseous state, and of the products resulting; and thirdly, that of the lavas and other matters ejected in a solid or liquid condition: from whence we shall be led to examine, the depth at which volcanic action is seated, and lastly, the mode in which the mountains, are built up of materials before considered.

Geographical Distribution of Volcanos.

Volcanos are said by Von Buch, either to occur scattered at certain distances along particular *lines* of country, or else to be united in clusters around some common centre.

The former he calls linear, the latter central volcanos; and whilst he regards the linear, as being in general produced in the direction of the fissures caused by the igneous operations of a former period, over which the primary ranges of mountains have been upheaved, he considers the central, as taking place in all kinds of positions over the Earth's surface, however much detached they may be from any of those leading systems of eleva-

tion, wherever the force which has been set in motion by volcanic agency is able to overcome the resistance opposed by the superincumbent rocks. In the former case the direction taken by the volcanic forces is determined by the previous configuration of the country; in the latter it takes place without reference to the nature of the pre-existing rocks.

It may, perhaps, be doubted, whether even the central volcanos enumerated by Von Buch, may not in some instances at least admit of being referred to some common system; but there can be no question, that the law which he has laid down with regard to the tendency of volcanos to burst forth in certain lines of country rather than in others, holds good very generally, and that many such groups may be enumerated; such as, that already pointed out as extending across the Greek Islands; (see pl. vi. fig. 5;) that stretching across Mexico, (pl. vi. fig. 3;) and still more remarkably the one, which, beginning at Barren Island, in the Bay of Bengal, may be traced along the Islands of Sumatra and Java, thence to the Philippines, and perhaps even to the Kurule Islands and to Kamtschatka. (See pl. vi. fig. 4.) The linear direction, therefore, of certain volcanic formations cannot be doubted; and the only question is, whether it prevails universally, or characterises, as Von Buch conceives, one particular class only of burning mountains.

Proximity to the Sea.

Another remarkable feature in the distribution of volcanos is their proximity to the sea; in proof of which it may be sufficient to remark, that out of a catalogue of no less than 163 active vents enumerated by M. Arago as occurring in various parts of the known World, all, excepting two or three in different parts of America, and about the same number, of which we possess very imperfect information, in Central Asia, are within a short distance at least of the Ocean.

It is even found, that the very excepted cases, when examined, tend to confirm the rule; being so situated, that their connection, either with the Ocean, or with inland seas that may supply its place, becomes a matter of fair inference. In proof of this we need only refer to the descriptions we have already given of Jorullo; from which it appears, that distant as this mountain may be both from the Atlantic and Pacific Oceans, it is nevertheless connected with one or both through the medium of a chain of volcanic eminences; (see pl. vi. fig. 3;) and even the volcanos of Tartary, whose existence in an active condition is more problematical, may be connected with some of those extensive salt lakes, which seem to abound in the depressed portion of Central Asia.

Thus even those few cases, which may be brought forward as exceptions to the general rule, appear, when examined, to enter into it, so far as relates to the probable connection they denote with deep seas or lakes; whilst the occurrence of by far the majority of active volcanos in Islands and maritime tracts, and their entire absence from many extensive Continents, may convince us, that the processes are at least greatly promoted by such a position, and in their intensity bear a certain relation to the more or less ready access to them of water.

And, although extinct volcanos seem by no means confined to the neighbourhood of the present seas, being scattered often over the most inland portions of our existing Continents; yet it will appear, that at the time at which they were in an active state, the greater part were in the neighbourhood of those extensive salt or fresh-water lakes, which existed at that period over much of what is now dry land. Instead, therefore, of these being brought forward as exceptions to the generality of the rule, the cessation of such action, now that the water has left their neighbourhood, seems to furnish a confirmation of its truth.

Aeriform fluids evolved.

We have next to consider the ordinary products of volcanic operations, and shall begin by noticing the aeriform fluids evolved, regarding them as in a manner the prime movers of the effects we witness, the agents, by whose mighty power are propelled from the bowels of the Earth those solid matters, afterwards to be described, which, settling round the brim of the orifice from which they found an issue, grow at length into the form and dimensions of an ordinary crater of eruption.

During the active condition of a volcano, the aeriform fluid most copiously emitted probably is steam, which manifests itself in those white vapours which usually proceed from the crater during an eruption, and may assist in producing by its condensation the heavy rains which frequently succeed it, though we are more disposed to attribute these to the disturbance in the electricity of the atmosphere, which is evinced by the vivid lightning commonly observed during a volcanic eruption.*

Steam is also emitted, sometimes for ages together, from fissures called "stufas," on the flanks of many extinct as well as active volcanos; thus supplying us with a confirmation of the dependence of volcanic phenomena upon the presence of water.

The permanently elastic fluids commonly given out are, muriatic acid, sulphuretted hydrogen, sulphurous acid, carbonic acid, and nitrogen.

Of these the first, muriatic acid, seems to be generated during almost all the phases of volcanic action; for although some have attempted to establish a class of volcanos to which the production of muriatic acid was peculiar, yet it would seem that there were none from which this gas is not in greater or less quantity disengaged.

Thus it has not only been detected by Sir H. Davy, issuing from the flanks of Vesuvius soon after the eruption of 1815, but likewise from the same mountain whilst in a more quiescent condition in 1824.

It was also found by Professor Daubeny, in the vapours given off round the crater of the Island of Volcano, round that of Etna whilst dormant, and in that of the Solfatara of Puzzuoli; it has been discovered also in the volcanos of Iceland; in those of Java, at Mount Idienne; and of South America, at Puracè, accompanied in both these latter cases with a predominant proportion of sulphuric acid; nay, it has even been found in an uncombined state pervading the trachytic rock of the Puy di Sarcouy in Auvergne. Of the gaseous compounds of sulphur, one, the sulphurous acid, appears to be predominant chiefly in volcanos possessing a certain degree of activity, whilst the other, sulphuretted hydrogen, seems to be emitted for the most part when they are in a dormant condition.

* Sir H. Davy, in his Memoir on Vesuvius, remarks that it was easy, even at a great distance, to distinguish between the steam disengaged by one of the craters, and the earthy matter thrown up by the other. The steam appeared white in the day, and formed perfectly white clouds, which reflected the morning and evening light of the purest tints of red and orange. The earthy matter always appeared as a black smoke, forming dark clouds, and in the night it was highly luminous at the moment of the explosion.

Thus sulphurous acid is given off in large quantities from the craters of Etna and Vesuvius, and even from that of Volcano in the Lipari group, whilst sulphuretted hydrogen is observed at the Solfatara of Puzzuoli, on the skirts of Etna near Jaci Reale, and in many hot springs connected with dormant volcanic action both in these regions and elsewhere.

Not that we are obliged to suppose sulphurous acid to be entirely absent in the latter cases, or sulphuretted hydrogen in the former; for as these two gases, when they meet, decompose each other, forming water and depositing sulphur, it is reasonable to expect, that only that portion of either which exceeds the quantity necessary for their mutual decomposition will escape from the orifice, so that the gas that actually appears, only indicates the predominance of the one, and not the entire absence of the other.

Carbonic acid appears to be chiefly found in volcanos that have become extinct, and when it occurs in those considered active, it is at a time when they are not in a state of eruption. It is also found to occur more commonly at the foot and in the neighbourhood of volcanic mountains, than in their craters, or at the points of their most vehement action; so that it may be viewed, rather as one of the consequences of a long continued operation of the heat produced upon the contiguous rocks by volcanic processes, than as the direct effect of the processes by which that heat is occasioned.

The last of these gases, nitrogen, has been already sufficiently alluded to: from the observations hitherto made, it would seem to be for the most part the concomitant of languid volcanic action; but it is probable, that, when the gases evolved from active volcanos have been scrupulously examined in a greater number of cases, it will be noticed much more commonly as occurring amongst them; since Sir H. Davy detected it, in Vesuvius, and his brother Dr. John Davy, in the gas given off by the new volcanic Island near Sicily, in both cases accompanied with less than the usual proportion of oxygen.

Substances not gaseous ejected.

Other substances are often disengaged from volcanos as vapours, but condense round its exterior either in a liquid or a solid condition.

Such is the petroleum found by Breislac, at the foot of Vesuvius, the Val di Noto in Sicily, the extinct volcanos of ancient Latium and Auvergne, the site of the ancient eruption recorded in the Book of *Genesis* on the spot now occupied by the Dead Sea, and many other localities. Such also is the sulphuric acid, which has been only hitherto met with in extinct volcanos; as for instance in a stream issuing from that of Puracc between Bogota and Quito, from one derived from Mont Idienne in Java, and probably in the rocks connected with the languid operations about Radicofani in Tuscany. It is obviously derived from the sulphurous acid, which, passing through the water of some volcanic lake, and absorbed by it, has derived an additional dose of oxygen from the atmospheric air present.

The solid substances sublimed by volcanos are, 1. the boracic acid, found in the crater of Volcano, and the Lagunes of Tuscany, which, though it remains fixed in our furnaces, appears to be evolved in vapour by the heat of these volcanos. 2. Muriate of ammonia, very abundantly evolved during certain eruptions, as by that of Etna in 1780, but apparently absent from others. 3. Specular iron ore, probably disengaged in combination with chlorine, which latter principle may be separated, on its coming into contact with the atmosphere, by means of the heat, water, and oxygen of the air. 4. Muriate of soda, the most abundant of them all, as well as the most universal, being exhaled more or less by almost all volcanos, and present even in their lavas, according tô Monticelli, who obtained more than nine per cent. of it, by simple washing, from that which issued from Vesuvius in 1822.

We do not include among the sublimations, the deposits of sulphur, or the sulphurets of iron, copper, arsenic, and selenium; still less the various sulphuric salts found efflorescing in the spiracles of all volcanos.

The sulphur, which seems to be of almost universal occurrence wherever volcanic operations are going on, is evidently derived, in the majority of instances, from the mutual decomposition of the sulphurous and sulphuretted hydrogen gases; for we know of no well authenticated case of its sublimation in an uncombined state from any volcano, and analogy would lead us to extend the same inference, to the compounds of sulphur with arsenic and selenium, that occasionally accompany it.

The sulphates of lime, alumina, iron, magnesia, and soda, which so frequently incrust the surfaces of recently ejected masses, or the fissures of volcanos in present action, are evidently produced, by the affinity exerted by the sulphuric acid, which has proceeded from the sulphurous acid disengaged, for those alkaline and earthy bases with which it may have come into contact.

The substances hitherto considered, in whatever condition they may present themselves to the eye of the observer, have evidently been either disengaged from the volcano in a gaseous form, or at least have resulted from the same; but we have next to consider those, which have been thrown out in a solid or a liquid state from the crater, but without becoming, like the former, volatilized by the action of the heat.

Solid Substances ejected.

They may be divided, into such as have undergone a complete change from the process, amongst which we comprehend lavas, and loose ejected masses of similar composition; and such as are thrown out, either unaltered, or at least retaining enough of their original characters, to be identified with some one or other of the existing rocks.

Lavas.

Their Chemical Characters.

Beginning with the former class of substances, I shall first state the chemical, and afterwards the mineralogical characters of lavas.

Lava, when observed as near as possible to the point whence it issues, is, for the most part, a semifluid mass of the consistence of honey, but sometimes one so liquid as to penetrate the fibres of wood. It soon cools externally, and therefore exhibits a rough unequal surface; but, as it is a bad conductor of heat, the internal mass remains liquid, long after the portion exposed to the air has become solidified. The temperature at which it continues fluid is considerable enough to melt glass and silver, and has been found to liquefy in four minutes a mass of lead of such a size, as, when placed on red-hot iron, to require double that time to enter into fusion.

Stones of a spongy nature, pumices probably, were melted when thrown into the lava of Vesuvius; that of Etna is said to have effected the same; and a current, which proceeded from an Iceland volcano, is stated to have melted down every kind of hard stone that came in its way.

On the other hand, masses of limestone have been taken out from the midst of lava with no signs of fusion upon them, and even with their carbonic acid undiminished; and the houses of Torre del Greco, and of other villages, which have been enveloped in liquid lava, remained unmelted by it. When bell-metal was submitted to the action of the Vesuvian lava of 1794, the zinc was separated, but the copper continued unaffected.

Sir James Hall, in his Memoir on Whinstone and Basalt, has presented us with a Table of the relative fusibilities of seven specimens of whin or basalt from the neighbourhood of Edinburgh, and of an equal number of lava from various European localities; from which it appears, that when converted into the state of glass, they become softened at a temperature from 15° to 24° of Wedgwood, or 3027° to 4197° of Fahrenheit. Whilst in a crystalline state, the same ingredients continued solid at this temperature, but became soft at one varying, from 28° to 55° of Wedgwood, or from 4717° to 8227°, a heat inferior to that of a common glass-house.

With this statement regarding the melting point of these ignigenous products, the chemical composition, which appears to belong to them, is in complete accordance.

According to Dr. Kennedy, two specimens of the lava of Mount Etna contained each 4 per cent. of soda, and nearly 15 of oxide of iron, to 51 of silex, 19 of alumina, and about 10 of lime. Other lavas, doubtless, are differently constituted, and some appear to be completely destitute of alkali; yet even in these latter cases the presence of some alkaline earth, capable of acting as a flux to the silex and alumina, seems universally to supply its place; and accordingly, there are few varieties, that do not readily fuse at the heat of an ordinary blast furnace, and some, indeed, at a much lower temperature.* Nevertheless, there are circumstances, which have induced certain Naturalists to adopt quite a different view of the nature of lavas, and to imagine them to owe their fluidity, not to the intensity of the heat, but chiefly to the presence of some solvent or flux.

This opinion was originally broached by Dolomieu, who founded it upon the assumption, now admitted to be erroneous, that the crystals of augite and hornblende which lava contains, existed antecedently to the fusion of the mass, and were not produced in consequence of it. Hence he necessarily concluded, that the lava could only have been subjected to a degree of heat, inferior to that at which such crystals would become fused.

Finding, therefore, sulphur to be exhaled from certain lavas, he imagined this to act as a flux to the other substances, and accounted for the more difficult fusibility of the mass when once cooled, from the escape of the sulphur originally present. The existence of sulphur in lavas has been asserted by some, and denied by others, but whether it be present or not, there seems no necessity for attributing to it the fusion of the mass, when, as we have seen, its composition alone sufficiently accounts for this circumstance.

* According to Saussure, *Journal de Physique*, an. 2, felspar melts at 70° of Wedgwood, basalt at 76°, and hornblende at about 100°.

It must in any case be disengaged very soon after the melted matter has been ejected, for no sulphurous vapours are perceived to issue from a lava current of old standing, even though it may continue internally fluid; and it is well known, that sulphur forms no part whatever of the composition of lavas, and can, therefore, only be mechanically mixed with them.

A recent Geologist has lately brought forwards a modification of Dolomieu's theory, by supposing water to act the part which the latter attributed to sulphur; and although we are compelled to reject his theoretical views on this subject, as utterly inconsistent with known chemical principles, yet they suggest some interesting inquiries, with respect to the state in which those volatile matters existed in lava, which are said to be copiously disengaged from it in the state of vapour. Have they been confined by the pressure of the superincumbent mass, until its gradual cooling caused fissures by which they were enabled to make their escape, or is it possible, that the influence of pressure may be assisted by some kind of chemical union between them and the other constituents? All writers admit, that various salts are emitted from the surface of recent lava, which are never found amongst its constituents; and if these are sublimed, as appears to be the case, by the heat, the same may also happen with regard to the other more volatile matters, whose extrication from lava is vouched for on respectable authority.

Their Mineralogical Characters.

The mineralogical characters of lavas have been already given at the commencement of this Article, where they are stated to belong in general to the rock called by Mr. Scrope greystone, and by M. Brongniart tephrine, consisting essentially of felspar, with many accidental ingredients superadded, such as olivine, mica, augite, hornblende, titaniferous iron, and the like.

Loose Fragments ejected.

The loose fragments ejected from the crater differ but little in mineral composition from the continuous streams of lava, but they are generally of a more cellular and porous aspect, not uncommonly fibrous, and consequently more brittle and incoherent. They also frequently present that vitreous appearance which is the effect of sudden cooling, and vary in size from masses many tons in weight to a fine and impalpable powder.

There seems, therefore, good reason for suspecting, that all those volcanic products which we have just been considering, in whatever form they may have issued from the volcano, are allied to the rock denominated trachyte; and, that they are either derived from it, or, at least, formed out of the same materials as those of which the latter is composed, appears from our finding, that, in many places where the structure of a volcanic mountain has chanced to be exposed, the lowest in the series of formations that present themselves to the eye is of a trachytic nature, and that the strata superincumbent often seem to show a resemblance to that rock, more or less close in proportion to their contiguity to it.

Trachyte, whence derived.

Trachyte, also, is a rock of such universal occurrence in volcanic Countries, and so abundant in those in which the action is of the most remote date, and has taken place on the most extensive scale, that it seems to be natural to derive the lavas subsequently ejected from it,

regarding them merely as so many modifications of this original material, more or less changed by the larger continuance of the heat, or the admixture of other matters.

But, considering the peculiar characters and composition of trachyte, as well as the circumstance of its being limited to Countries that appear to have undergone the action of volcanic fires, we can hardly regard it as a substance which makes a part of the original constitution of the Globe, and shall be disposed to set it down, as itself a product, although a primary one, of the fusion of other kinds of rock. Of what nature this latter may consist, will, perhaps, be determined, if we examine, first, with what particular descriptions of rock trachytes are most connected in point of situation; and secondly, to what they present the nearest resemblance in mineralogical and chemical composition.

The former inquiry will lead us to consider, in the first instance, the nature of those ejected masses which appear to belong to the contiguous rock formations, and not to be products of the igneous operations to which their ejection has been owing.

Among these, we read of no substance bearing the slightest resemblance to the constituents of secondary or tertiary strata, but of many which may, with the greatest probability, be referred to rocks of a granitic character.

Thus at the Puy Chopine in Auvergne, granite is found intermingled with the trachyte and greenstone, thrown together in confusion, as if the whole had been elevated at one time, before the rock had been entirely changed by the process.

In the lavas of the Vivarais, in those of the Rhine, and in other localities, imbedded masses have been met with, having much the appearance of an altered gneiss or granite. Humboldt mentions his having found, in the midst of the new volcano of Jorullo in Mexico, white angular fragments of syenite, composed of a small portion of hornblende, with much lamellar felspar; Gemellaro discovered a mass of granite containing tinstone amongst the ejected masses of Mount Etna; and the same rock has been discovered amongst the trachyte of the Ponza Islands by Mr. Scrope, and in the lava of Vesuvius by Dr. Thomson of Naples.

Mica slate has, in one instance, been found ejected by Vesuvius, and various granular limestones of a dolomitic character are found amongst the masses ejected from the old crater of Vesuvius, which lie accumulated in the Fossa Grande, and other hollow ways on the slope of the volcano. It must be remarked, however, that these latter are never imbedded either in the lavas or in the volcanic masses ejected, so that they do not stand in the same relation to them, as the granitic masses do which have been before enumerated.

With regard to the formations, in which trachytic rocks, or, to speak more generally, volcanos, usually appear, great discrepancy seems at first sight to exist.

Thus, to begin with the Rhine, the formation on which the trachyte of the Siebengeberge rests, and among which the volcanos of the Eyfel have arisen, is a clay slate belonging to the transition series; in Auvergne, the rocks of Mont Dor and of Clermont rest immediately upon granite, or are separated from it only by a tertiary deposit, whilst those of Cantal are incumbent on mica slate. In Hungary the rock underneath is a porphyry, associated with syenite, clay slate, &c. and referred by Beudant to the transition series; in Transylvania, according to Boué, the trachytes lie near the mica slate and gneiss, with which are masses of syenite and marble; whilst in Styria, the rock most immediately surrounding the little trachytic formation of the Gleichenburg, is gneiss.

In Italy the case is somewhat different; yet, though the trachyte of the Euganean hills rises from beneath chalk, we have reason to believe that primitive and transition rocks lie at no great depth beneath, as they are found near Schio, and support the alternations of volcanic and neptunian deposits in the Braganza.

Humboldt has shown, that the rock which supports the volcanos of the New World is generally a transition porphyry, and sometimes granite or syenite; and Von Buch reports, that the last-named rocks appeared as the lowest of those uplifted strata, which surrounded the crater of the Island of Palma and other of the Canaries. Now, although the preceding enumeration indicates such a variety with regard to the position of volcanic formations as may seem at first sight to baffle all general conclusions; yet when we consider, that, in the majority of instances, the rocks have been referred either to the primitive or the transition series, and that in the remaining ones, the latter were at a depth far less considerable, than that at which we shall afterwards find reason to conclude, that the volcanic force itself resides; it may not be unfair to presume, that volcanos have universally broken out amongst the older formations, or those most near to the nucleus, whatever that may be, of the Globe.

It is obvious, indeed, that in those cases in which volcanos have appeared in the midst of primitive rocks, we cannot presume the seat of action to reside amongst those of a later date, but that the converse does not hold good; so that if we only admit, that any certain position is to be assigned to these products, a single case of their occurrence in the midst of older formations would overturn every inference to be derived, from their being observed to emanate from strata of a more recent date.

The legitimate deduction from the above facts are, moreover, strengthened by considering the mineralogical and chemical constitution of trachyte, both which bear such a resemblance to that of granite, that the rock has been called by Dolomieu granitoid lava.

And although the two rocks may be distinguished, by the presence of quartz in the one, and its absence from the other, yet the predominance of felspar in both seems to place them in the same genus, and to distinguish them from the constituents of secondary strata, where that mineral hardly can be said to occur, except where we have reason to suspect the agency of fire.

It is probable, too, that the chemical composition of granite and trachyte taken from the same localities, would not be found to vary materially, notwithstanding the differences in their mineral constitution pointed out.

Thus, though quartz is wanting in trachyte, and abundant in granite, yet the silicious earth contained in that mineral, may have united with the alumina present, in such proportions as would form felspar, and in this manner the latter may have become more abundant, at the expense of the other two ingredients of the granite.

In some cases, on the contrary, where the material operated upon consisted chiefly of quartz, the result may have been that variety called millstone trachyte, which, though chiefly silicious, betrays its igneous origin by the cells and cavities it so abundantly contains.

If, then, there be reason to conclude, that the substance, which has supplied the materials ejected by

burning mountains, or constituting their internal nucleus, be derived from granitic rocks, a strong argument will be afforded, in favour of the great depth at which the operations are seated, that have given rise to the effects we witness.

This inference, indeed, is greatly strengthened by a consideration of the phenomena attendant on an eruption, the general tenour of which plainly denotes, that the focus of the action is situated at a depth at the least as great, as that to which granite may be supposed to extend.

We do not, indeed, lay any stress on the remarks of Stukeley, who calculates from the compass of country over which earthquakes have been felt, that the force must, in some instances, be 200 miles beneath the surface, because we have seen reason to believe, that vibrations may be propagated laterally beyond the immediate influence of the impelling force; but we would argue, from the immense mass of materials ejected by any one volcano, as for instance by Etna or Vesuvius, without exhausting itself, or causing any sinking of the mountain; from the prodigious height, to which the trachytic nucleus of others seems to be raised, as at Teneriffe and in Equinoctial America; and, lastly, from the immense violence of the eruptions, which would shiver into pieces any merely superficial covering of rock, that the elastic vapours must be disengaged at a depth at least as great, as that to which the crust of the earth can be supposed to extend.

Constitution of a Volcanic Mountain in general.

Having now examined the products of subterranean fire individually, we will next consider them in the aggregate, and explain the manner in which they produce those vast accumulations of volcanic materials, which occupy so large a portion of the surface of our Globe.

Those observers, who have been fortunate enough to obtain a near view of the crater of a burning mountain, in what is called its active condition, inform us, that the interior of it is filled with a body of melted lava, which may be seen alternately rising and falling within the chasm. At its maximum of elevation, one or more immense bubbles have been seen to form on the surface of the lava, and rapidly swelling, to explode with a loud detonation. This explosion drives upwards a shower of liquid lava, which, cooling rapidly in the air, falls in the form of scoriæ. The surface of the lava is in turn depressed, and sinks several feet, but is propelled again upwards in a moment by the rise of fresh volumes of elastic fluids, which escape in a similar manner. Such is the account given by Mr. Scrope of the crater of Stromboli, which he surveyed from a commanding point of rock; such likewise in the main is that given by Spallanzani of Etna, by Bory St. Vincent of the volcanos of the Isle of Bourbon, and by Ellis of Kirauea, in Owhyhee. In all these cases, a mass of melted matter, of unknown depth, covered for the most part with a thin pellicle of scoriform lava, and emitting copious volumes of steam or gas, was observed in the crater which they overlooked.

Now it is evident, that the tendency to eruption in all these cases will depend upon the relation existing between the expansive energy of the materials and the controlling force, derived, in part, from the pressure of the superincumbent atmosphere or ocean, and in part, from the weight of the column of liquefied matter; and as in general a considerable proportion of the matters ejected during a paroxysm of volcanic action falls back into the crater, whilst the elastic fluids, which served to expel them, escape, the active state of a volcano will in these cases be intermittent, and its eruptions placed at distant intervals asunder.

In a few rare instances, as at Stromboli, where, from some peculiarity in the configuration of the mountain, the whole of the ejected materials falls into the sea, and is carried away by a strong current to a distance, the repressive and expansive forces may be so equally balanced, that a series of explosions shall occur at short intervals, for any length of time during which the volcanic processes continue, without any accession of violence ever taking place, sufficient to produce the emission of a continuous current of lava. In cases where the opposite forces are so nicely balanced, it may happen, as Mr. Scrope has ingeniously suggested, that the mere variations of atmospheric pressure would cause a difference in the explosive force, and thus may explain what the inhabitants of that Island are said to have remarked, that the intensity of the eruptive violence is greatest in stormy weather.

Craters of Eruption.

It is evident, then, if we suppose this to be the condition of every active volcano, that, when once the violence of its operations has arrived to such a pitch, as to overcome the resistance opposed to it, the elastic vapours will throw out portions of the liquid lava, just as, when a mass of melted metal happens to fall into a vessel containing water, the steam generated disperses it in all directions. These portions of lava projected into the air, descend again in the form of scoriæ or sand, and collect into an aggregate, which is called, rather improperly perhaps, a bed of volcanic tuff.

But the projection of these fragments is soon followed by the overflow of the melted lava itself, which by degrees reaches the brim, spreads over the tuff, and forms a regular bed encircling the original aperture.

Now the repetition of these successive operations would cause just that alternation of beds of lava and tuff, which is found to constitute the sides of most volcanic craters, and it will be at once seen, that the direction in which they lie, to appearance horizontal, when viewed from the interior of the chasm, but in reality dipping on all sides away from the centre at an angle of about 30°, is exactly what would happen, if we suppose them formed in the manner represented. In plate v. fig. 9. the disposition of the beds in a crater of eruption is given, and, as contrasted with it, is shown that of the beds on a hill, which may chance to have been hollowed out by the action of water, in a manner, which causes it to correspond in external appearance with that belonging to the crater, after the latter has been broken away, and partially destroyed, by the agency of other causes.

It is true, that we can hardly imagine many hundred alternations of strata so constituted to mantle round the crater in the way supposed; for it is evident, that the slightest irregularity in the brim over which the lava flowed, or upon which the scoriæ descended, would determine these materials more on one side than the rest, so that we should never find, after the first few beds had been formed, any that actually extended round the whole circumference.

But Professor Lyell has stated from actual observation, that this appearance of uniformity is delusive, and

that the cone is in reality composed of a number of beds, each of which thins out so gradually, as to be confounded, and to appear continuous, with some other placed next it.

Craters of Elevation.

The above statement of the ordinary succession of phenomena occurring during a volcanic eruption, which we owe originally to M. Neckar de Saussure, supplies us with a very simple and natural explanation of the structure of an ordinary volcanic cone, the quaquaversal dip of its strata, the regular alternation of tuff and lava, and even perhaps of the dykes which intersect them. But are we at liberty to infer, that the whole of a volcanic mountain, whatever may be its form, antiquity, or position, whether situated, like Vesuvius, on the borders of the sea, or like the Peak of Teneriffe in the midst of a fathomless ocean, is built up entirely after this fashion?

Even in the absence of any direct evidence on the subject, we should be inclined to hesitate before we adopted such a conclusion, and to ask ourselves whether, under so enormous a pressure as that of the Ocean, the expansive force of elastic fluids, struggling to escape, would not be more likely to upheave in the first place the strata nearest the focus of the action, when softened by the heat, within a given area, than to eject fragments of rock round a cone in the manner represented.

We might also feel perplexed to explain on such a supposition the appearance of any detached volcanic mountain in deep water, since such materials, if accumulated under the sea, would be too quickly diffused over its bottom, to raise the level to any considerable height at one particular point.

It would also seem, that if earthquakes are allowed to have brought about an occasional upheaving of the Earth's surface, and that, without producing such a confusion of the strata affected, as even to interfere with the springs of the country, or to throw down the buildings erected on the spot, there would be still greater reason for attributing the same effects to volcanic action exerted upon rocks which have been actually softened by the previously existing heat.

But independently of these probabilities, there are not wanting direct proofs of the upheaving of rocks, that appear to be connected in some way with volcanic operations; proofs derived, in some cases from the appearances they present, and in others from the actual testimony of eye-witnesses.

Upheaving of Volcanic Mountains shown,

First, by their own appearances.

The former are drawn from the examination of volcanic mountains, whose interior structure is from some cause or other in such a manner exposed to view, as to reveal to us the real nature of the material which composes its nucleus.

Thus in the Island of Great Canary, and still more remarkable in that of Palma, a chasm called the Caldera exists, nearly 4000 feet in depth, which afforded to Von Buch an excellent section of the internal structure of the mountain itself. Lowest of all he discovered the primitive rocks, then masses of trachyte, and above various alternations of those volcanic strata which usually occur in craters. The latter, for ought we know, may have been formed by successive ejections of lava and scoriæ; but the trachyte and the granite underneath must have been upheaved, for why else do we find them at a height, which, though 4000 feet perhaps from the summit, is at least 3000 from the base of the mountain, and consequently from the level of the sea, and that sea too unfathomable? Can we resist the belief, that at least the granite with its superincumbent trachyte were upheaved from the bottom of the Ocean by volcanic agency, and thus constituted a nucleus, round which the subsequent ejections have taken place? Ought not such an example to be regarded as more conclusive, than the observations of a contrary tendency which other Geologists have recorded, with respect to the appearances presented in some of those deep valleys, which exhibit sections of the interior of the volcano?

Where, as in the case of the Val de Bove on Mount Etna, the structure is similar to that which at present results from the eruptions, that from time to time take place, we have doubtless a right to assume that they were produced in a similar manner, and consequently the antiquity of the volcano is enhanced, in proportion to the extent of the series of strata so exposed; but we are not therefore entitled to conclude, that the original formation of the volcano must have been of the same nature with that of its subsequent growth, still less to extend the same inference to other volcanos that may appear differently constituted.

Secondly, by the Existence of Domes of Trachyte.

Of the upheaving of trachyte in detached dome-shaped or conical masses, and that by forces which we can hardly hesitate to regard as volcanic, examples, we conceive, of even a less equivocal kind, may be found, in Countries more accessible to the European traveller.

To what other cause, for example, are we to attribute the occurrence of those five isolated hills of domite, which we meet with near Clermont in Auvergne, the largest of which, the Puy de Dome, rises nearly 3000 feet above the general level of the plateau on which it rests?

On what possible supposition are we to account, for the regularity of their form, their perfectly detached position, and their occurring, each in the midst of an amphitheatre, composed of volcanic rocks of a totally different kind? Shall we imagine them to be the relics of a continuous stratum, once spreading over the adjacent country, but since removed by subsequent changes? or shall we suppose them to be masses of a kind of lava, which, from its imperfect fluidity, accumulated round a central point, without spreading into the adjacent plain? The former supposition seems irreconcilable with the fact of the total absence of all traces of the rock elsewhere, and with the conical form belonging to some of these masses; the latter is manifestly inconsistent with its chemical constitution, and the idea of its owing its fluidity to intense heat, which we have thought fit on other grounds to adopt.*

In one of these hills, the Puy Chopine, we appear even to be able to trace the very steps by which the process has taken place. We observe here, not merely a rock composed of that variety of trachyte, which in the

* See this question more fully discussed in a Letter to Professor Jameson, on the Diluvial Theory, and on the Origin of the Valleys of Auvergne, by Professor Daubeny, published in the *Edinburgh New Philosophical Journal for April*, 1831.

other four hills constitutes the whole mass, but by the side of it, forming the side fronting the South-west, South-east, and East, a congeries of various primitive and volcanic rocks in different states of alteration. We may enumerate, a conglomerate of scoriæ and volcanic tuff, of basalt, hornblende slate, sienite, and granite, more or less disintegrated, especially where in contact with the trachyte. The whole of the mountain is surrounded by an amphitheatre of rocks composed of a congeries of scoriform volcanic products, from the midst of which it appears to have been elevated; so that we seem to have at once presented before our eyes, the material from which the trachyte was elaborated, the several steps in the process of change effected, and the mode in which, when so prepared, it was made to occupy its present position.

If, however, we believe Humboldt, the New World must present a much more decisive instance of the kind, than the Puys of Auvergne we have been just considering; since Chimborazo, the highest mountain in that hemisphere, is represented by him, as composed entirely of trachyte, and being, both in form and composition, on the great scale, what the Grand Sarcouy in Auvergne is on a smaller one.

Now we may remark, that it is only because these mountains, owing to the shifting of the volcanic fire to another quarter immediately after their elevation, or to some other peculiarity in their physical condition, have given rise to no ejections of lava or scoriæ, that we are enabled to ascertain so decisively their constitution; for had they assumed the character of permanent vents, and consequently been covered, as Etna and Vesuvius are, by a numerous succession of layers of volcanic materials, we should then have been induced to conclude, that they were entirely built up of that, which constituted in reality merely their external superficies.

There are also not wanting instances in volcanic districts, where the ordinary rocks of the country have been heaved up round a circumscribed area, evidently by the expansive force of vapours from beneath, so as to form crater-shaped cavities, resembling in all particulars, except in their component parts, that assumed by a volcano. Mr. Scrope himself has described one of them in page 74 of his *Memoir on Central France*, where he makes mention of a circular lake called Le Gour de Tazana, about half a mile in diameter, and from thirty to forty feet deep. Its margin, for a fourth of the circumference, is flat, and elevated above the valley into which the lake discharges itself. Every where else it is environed by steep granitic rocks, thickly sprinkled with small scoriæ and puzzolana, and rising about 200 feet from the level of the water. These fragments are all that indicate the volcanic origin of this gulf-like basin, but they are sufficiently decisive. No stream of lava, or even fragments, of any large size, are perceivable.

Similarly formed craters occur likewise in the Eyfel; and perhaps the best example of them is the circular volcanic lake called the Meerfeld, hollowed out of transition slate and red sandstone, without any admixture of volcanic matter, though surrounded by loose fragments of augitic lava. Now if we admit, that in these instances, the rocks in question have acquired their actual position from the operation of expansive vapours acting from below, what reason is there for questioning the possibility of the same forces having acted likewise upon volcanic strata, and caused them to be upheaved in a similar manner?

Even limestone rocks, if we believe Von Buch, have sometimes been elevated by volcanic agency in a conical form, so as to imitate in their appearance the trachytic masses mentioned as occurring in Auvergne.

Instances of this kind are met with between Trent and Roveredo, and it is remarkable, that the rock in every case is of a dolomitic character, whereas the limestones in the neighbourhood are destitute of magnesia. The same remark applies, as we have seen, to the ejected masses of granular limestone found at Vesuvius, which are dolomitic, although the apennine limestone of the neighbourhood is in general not magnesian.* (See pl. iv. fig. 7. 8.)

Hence Von Buch has had the boldness to attribute this latter ingredient to the volcanic action, imagining the Earth in question to have penetrated the volcanic matter whilst in a liquid or pasty condition, so as to form with it a chemical compound.

There are, it must be confessed, weighty difficulties in the way of such a supposition, and in some of the spots which Von Buch has appealed to in proof of his theory, as, for instance, at Gerolstein in the Eyfel, the circumstances are such as to preclude us from adopting such a supposition, without a manifest anachronism;† nevertheless the singular appearances of these rocks, and their connection with the surrounding strata, have induced many to suspend their judgment, and to regard the impregnation of limestone with magnesia, in the manner supposed, as one of those facts, which a more advanced stage of chemical knowledge may explain, or at least render more conceivable.

Even those who reject this theory of Von Buch's, will hardly hesitate to regard the curved stratification, manifested not unfrequently in our sections of the Earth's surface, as caused by an upheaving force. We are indebted to Mr. Bakewell for presenting us with an instance, which seems to comprehend all the conditions requisite for establishing this view of the case. Four miles East of Matlock, in the isolated hill called Crick Cliff, about 900 feet above the Derwent, the strata rise in all directions towards the central point, so as to form nearly spherical segments. (See pl. iv. fig. 6.)

The true structure of the hill has been discovered by recent mining operations, several valuable metallic veins having been explored in it, and a gallery driven in it, as represented in the figure.

Now it is obvious, that, although the inclination of plane strata may result from subsidence, such an arched structure as that represented could hardly have been formed except by protrusion, of which its proximity to beds of toadstone, to which we ascribe a volcanic origin, suggests an explanation. In this instance, however, we are not left to conjecture; for lately, in driving the gallery on towards the centre of the hill, a mass of toadstone was met with; and the same was found, by sinking a shaft from the top of the hill, so that the cause and the effects are at once displayed, in the section we are enabled to give of this hill.‡

* In fig. 7. is an ideal section by Von Buch of the rocks in the Val de Fassa, Tyrol, showing the manner in which he conceives the pyroxenic porphyry to have first heaved up and displaced the shelly limestone, together with the other rocks, and afterwards to have converted it into those masses of dolomite which cap the summits of the overhanging mountains.

In fig. 8. a drawing is given of one of these dolomitic mountains; and the position of the porphyry, the shelly limestone, and the red sandstone with reference to it, is indicated by the annexed figures.

† See Daubeny, *Description of Volcanos*, p. 53.

‡ See Bakewell, *Geology*, 1833.

Testimony in favour of the Elevation of Volcanic Rocks.

But if the appearances which are presented by many of the rocks affected by volcanic fire lead to a conclusion favourable to the notion of their having been uplifted; still more decisive is the evidence afforded us by those persons, who have either been eye-witnesses of the formation of a volcano in a new site, or have been situated, nearest in point of time or place, to the theatre of such events.

Father Gorce, in 1707, was eye-witness of the appearance of a new rock, between the two Islands of Great and Little Cammeni, off Santorino in the Grecian Archipelago. He states, that it gradually increased in size and in height, until it became half a mile in circumference, and rose twenty or thirty feet above the level of the sea, bringing up with it live oysters. After this had happened, a crater appears to have been formed, from which fragments of volcanic matter were ejected, and the latter now cover the surface of the Island, and conceal the underlying rock.

Among the Aleutian group, Langsdorf has described a rock near the Island of Unalaschka, 3000 feet in height, consisting of trachyte, which made its appearance in 1795, and seems to have been thrown up all at once from the bottom of the Ocean. The Island that has recently appeared in the Mediterranean between Sicily and the African coast, though the part elevated above the sea was made up of scoriform matters disposed in concentric layers round a central orifice, seems below to have consisted of an upheaved mass of rock. It is certain, at least, from Captain Smyth's account, that the depth of the water on the site of the Island was at least 100 fathoms, when he sounded it in 1814; and it appears from the chart accompanying Dr. Davy's Paper, that it varies in the immediate vicinity of the Island from 1 to 12 fathoms, from whence it gradually increases, so that at a distance of from 100 to 200 yards from it, the present soundings are from 20 to 65 fathoms.

Now this change of level may no doubt be explained in two ways; either by the gradual accumulation of scoriæ and other volcanic products, or by the more sudden elevation of a portion of the bed of the Mediterranean. With either hypothesis the structure of the crater is equally compatible; for it is natural to suppose that, after a conical mass had been upheaved, ejections of scoriæ might have taken place round a central point.

But with regard to the mode in which the operations of the volcano began, we are disposed to give the preference to the hypothesis of a sudden upheaving; for to have raised the bed of the sea from 100 to 10 or 12 fathoms water, would seem to require a longer continuance of volcanic operations than is noticed as having occurred on this spot, as well as a wider dispersion of the ejected masses over the sea than appears to have been the case. We hear indeed of scoriæ and ashes having been distributed in all directions, even to the coast of Sicily, but we do not find any sensible difference in the level of the sea recorded, excepting within an area of one or two hundred yards round the Island, from which central point, therefore, the sea appears to sink abruptly in every direction.

Phenomena of Jorullo.

Lastly, Humboldt has presented us with an instance, where, in the centre of the great table land of Mexico, and at a period not more distant than the middle of the last Century, both the descriptions given by the inhabitants of the country, who were actual eye-witnesses of the event, and the appearances exhibited at the time the spot was visited by himself, led him to the conclusion, that a large tract of ground from three to four square miles in extent was heaved up in a convex form to the height of 550 feet, and that from the midst of this protuberance arose six conical hills, the least of them 300 feet in height, and the loftiest, Jorullo, elevated 1600 feet above the level of the plain.

Certain English Geologists have lately questioned the soundness of this explanation, and have suggested that the convexity of the plain may have been produced by a simultaneous overflow of lava from the six cones, and that these, uniting into one sheet, may have formed a sort of circular pool or lake of lava.

But this solution seems to us clogged with still greater difficulties than that offered by Humboldt; for although it be true, that the viscidity of a lava current is such, that we ought not to suppose it subjected altogether to the same laws as those which regulate the flowing of a body of water, still it seems probable, that some trifling inequality of surface in the plain over which it has spread, some variation in the quantity of lava given out from the different orifices, would determine the sheet of lava to one point rather than to another, and thus produce a stream flowing in a given direction, instead of a lake of melted matter circumscribed within so definite an area.

It has been said, indeed, that the heaving up of a tract of land of this kind is unprecedented; but so, it may be replied, is the formation of such a convexity, by the mere overflow of a stream of lava proceeding from any existing volcano. And it must moreover be recollected, that, according to the very conditions of the theory advocated by those Geologists who have objected to Humboldt's views on this point, our historical records would embrace so very small a portion of the time occupied by any of the great physical revolutions of our Globe, that there appears the less reason, for circumscribing Geological reasoning strictly to the data obtained by actual observation, provided it assumes nothing inconsistent with the laws which the latter tend to establish.

Thus we have literally no record of any other volcano formed in a new site upon land, than this of Jorullo; for the throwing up of the Monto Nuovo near Naples can be regarded in no other light, than as a transference of the volcanic action, which is taking place at the Solfatara, or at Vesuvius, to another neighbouring quarter.

It may also be remarked, that the existence of a hollow space beneath a volcano, which may be accounted for, although it does not necessarily follow, from the uplifting of the rocks composing its nucleus, seems the best and most obvious means of explaining the phenomenon stated by Dr. Horsfield to have occurred in Java; where the mountain Papendayang, formerly one of the largest volcanos in the Island, is said to have given way, and in part to have fallen in, so that an extent of ground, fifteen miles long and six broad, was swallowed up in the bowels of the earth, with the destruction of forty villages and a large proportion of their inhabitants.

There seems, therefore, good reason to believe, that volcanic rocks have been heaved up, both in the sea and on land, by the expansive force of elastic vapours, a position of greater importance in a theoretical point of view than might be at first anticipated, seeing, that it justifies us in applying these same forces to the explanation of the more extensive elevations of mountain ranges,

of which Geology apprizes us, though, as of the elevation of cones of trachyte, history is silent concerning them. Now a belief in the elevation of isolated masses of rock may serve to reconcile us to certain opinions, with respect to the origin of volcanic craters, which, resting as they do on the authority of the two individuals, who have examined volcanos, on the most extensive scale, and under the greatest variety of aspects, deserve from us at least a patient and unprejudiced hearing.

Craters of Elevation.

Von Buch has distinguished the craters of volcanos into two classes: those produced by eruption, and by elevation. The former are brought about in the manner already pointed out by Neckar de Saussure and others, and are found in all volcanos which have given rise to currents of lava, or have constituted permanent vents of volcanic materials.

The latter are produced, owing to the upheaving of the crust of the Earth by the agency of elastic vapours round a certain limited area, and may, therefore, consist either of the older rocks of the country, or of the products that have been accumulated by antecedent volcanic operations. The one may be illustrated by the crater of Meerfield in the Eyfel, and that of the Tour de Gazana in Auvergne; of the latter (the Puy de Dôme) and other conical masses of trachyte afford, as we conceive, unexceptionable examples.

Now as the structure of a crater of eruption has been compared by Professor Lyell to that of an exogenous tree, which increases by layers deposited from without; so that of a crater of elevation may, to follow up the same analogy, be perhaps compared to that of an endogenous one, where the growth is caused by the protrusion of a mass from within. The question, therefore, is, in what way are we to determine whether a given crater, or, to speak more generally, a given volcanic formation, be the result of the one or of the other process?

And here we must refer to an excellent Memoir lately published by Messrs. Elie de Bourmont and Dufrenoy, who adopt the following method of distinguishing between the two.

When the sides of the mountain are covered with bands of lava circumscribed within narrow limits, we may fairly infer that they have been formed by successive ejections; when, on the contrary, the whole circumference of the cone is covered by a continuous sheet of volcanic matter, which is commonly the case where the substance of it is basaltic or compact, we may presume that it has once been nearly horizontal, and has since become upraised. The former may happen most commonly in those volcanos which are subaerial and at present in action, but the latter is the case generally in those which are subaqueous.

If we suppose a body of liquid lava to be ejected from the bottom of a deep sea, and consequently under the pressure of a considerable volume of water, a crust would quickly form over its upper surface, in consequence of the rapid abstraction of heat by the water immediately superincumbent; so that the lava subsequently ejected would be compelled, by the resistance opposed by this hard, unyielding mass to its progress upwards, to spread itself laterally in all directions; thus forming a sheet or tabular mass of lava extending over the bottom of the sea on which it was poured out.*

* See Delabeche's *Manual*, third edition, p. 125.

Now it is evident, that an explosion of gas taking place underneath a mass of lava, such as that represented, might produce a crater of elevation, by heaving up the lava round a given area, and producing a central cavity, through which the elastic vapours and solid matters ejected might continue to escape.

Messrs. Elie de Beaumont and Dufrenoy appeal to the elevated table lands of Mont Dor and Cantal, as affording instances of elevation, but as being altogether irreconcilable with the doctrine of craters of eruption; and it is certain, that if the sheets of trachyte are really continuous, we will not say over the whole of these mountains, but over any considerable portion of them, the notion of their being caused by successive ejections from a number of distinct craters, must be renounced as untenable. M. Virlet, indeed, one of the most distinguished opponents of the elevation theory in France, who accompanied the scientific expedition sent by the French Government to the Morea, is compelled to admit, that the eruptions, which built up the Mont Dor and the Cantal, must have been on a greater scale than any which we at present experience; thus giving up the very point which pleads most strongly in favour of the rival theory, by admitting, that causes now in action, operating with only their present intensity, are inadequate to produce the phenomena. On the other hand, the adversaries of Von Buch's theory in this Country, more consistent in their opposition, endeavour to show, that lava currents of equal extent have been produced in modern days; and doubtless Iceland, and even Sicily, afford examples, which may be fairly brought into competition with those of more ancient date.

But Messrs. de Beaumont and Dufrenoy contend, with great appearance of justice, that it is only when the lava has reached a tract of nearly level land, that it spreads itself over so wide a surface as is there represented, and that during its descent down the sides of the volcano it is almost invariably circumscribed within a very limited area.

When, therefore, we observe a conical hill composed of sheets of lava or trachyte, which can be ascertained to be continuous round the whole or the greater part of its circumference, we must suppose it once to have been horizontal, and afterwards to have been heaved up into its existing position.

Von Buch has, however, extended his theory to such craters as that of the Islands of Palma and of the Great Canary, assuming that all the strata observed in looking down from the summit of the Caldera have been upheaved, and that this deep chasm has been formed in consequence.

The Caldera of the Isle of Palma, says Von Buch, differs from a crater of eruption in many striking particulars. Here are no streams of lava, no slags, no lapilli, or ashes. Nor do we ever find the latter of such a circumference, or so profound and abrupt. Its general aspect seems to show, that it was formed by the pressure of those elastic fluids, which raised the whole Island above the level of the Ocean, and changed the strata composing it from an horizontal to their present highly inclined position. The aspect of those narrow and precipitous ravines, called Barancos, which encircle it, favours this hypothesis. They are so circumstanced, that we can hardly attribute them to the action of water; but if we suppose a succession of solid and unelastic strata to be suddenly lifted up in the manner of those in the Island of Palma, it is evident that not only would a central

aperture be formed where the crater now exists, but that the strain would occasion a number of lateral fissures, corresponding with those called in the Island Barancos.

To those, indeed, who have hitherto derived their notions on these subjects exclusively from English sources, we would recommend the perusal of the great Work on the Canary Islands, which we owe to the Prussian Geologist above mentioned. We shall there find a record of pheuomena, which seem hardly reconcilable to that theory with regard to the building up of volcanic mountains by the successive ejections of beds of scoriæ and lava, which, from its seductive simplicity, is calculated in a manner to preoccupy the mind of the Geologist.

We shall there see whole islands formed, of beds of basalt, not of scoriæ or of tuff, preserving in their external circumference a circular form nearly as perfect as that of the brim of their central crater, towards which they on all sides incline. We shall then see, in the midst of this amphitheatre, of basaltic rocks, and of other materials, which could scarcely have been formed excepting under water, a conical mass of trachyte rising to a great height with a crater in its centre,* and this crater one, which has not in all cases emitted lava currents or scoriæ, but has served only as a vent for steam or gases. Now, if these appearances can be best explained by an upheaving of rocks previously formed beneath the bed of the Ocean, what arguments of a general nature can be alleged to prevent us from adopting such a conclusion, seeing, that we are only extending to the materials of a whole island, what all admit with respect to certain isolated rocks; imagining that to have taken place in Palma, and the Great Canary, which we have almost been eye-witnesses of at the Islands of Santorino and Sciacca; proceeding, as it appears to us, legitimately, from the observed consequences of earthquakes at present, to the inferred effects of similar forces at periods antecedent?

That the hypothesis in question may have been pushed too far, and that some of the followers of Von Buch, originally misled by his authority, may have since been obliged to retrace their steps, is nowise improbable; but this does not invalidate the truth of the facts, which he and others have alleged, as applicable to the cases of Teneriffe, or Jorullo, or oblige us to imagine all volcanos, in whatever quarter of the Globe they may be, to be built up, after the model of those few on the borders of the Mediterranean, which chance to be most accessible to Europeans.

We hold, in short, that it would be just as illogical to argue, that because many craters have been built up by the gradual accumulation of successive eruptions, therefore that the same must have been the case with all, as to contend, that because the trachyte which forms the bottom of the Caldera has been uplifted, therefore that the strata superimposed upon it must have been so likewise, without reference to their nature or contents.

Both descriptions of crater probably have a real existence in nature, and the business of the Geologist, therefore, is to distinguish the one from the other, by a particular examination of each, and by considering, whether the strata that compose it have most the appearance of submarine lavas, or of those products, which are seen forming under our eyes by subaerial volcanos.

We have been disposed to dwell the more upon this theory of Von Buch, conceiving that justice has hardly been done to its pretensions by English Geologists, partly, in consequence of the original papers, in which his views were promulgated, having never been translated into our language, and partly, in consequence of their being somewhat at variance with certain doctrines in this Science, prevalent at the present time amongst us.

If, however, we may presume to act as arbiters between this great German Geologist, and his opponents in England, we should say, that the latter are perfectly justified in referring to processes of which they have daily experience, those craters to which both theories may be applicable, on the very same principle, on which we have ourselves given a preference to the simpler hypothesis advanced by Professor Forbes, and since so ably advocated by Mr. Lyell, to account for the phenomena of the Temple at Puzzuoli, (see p. 717.) though we have seen nothing to convince us, that the more complicated theory advanced by Goethe would not likewise account for them. On this principle we do not doubt that Hoffman has done right in retracting his original opinion with respect to Mount Etna being a crater of elevation, though we have yet to learn that this concession on his part ought to be construed into a general abandonment of Von Buch's theory as applied to other cases. On the other hand we would submit to our readers, whether, on reviewing the facts that have been put before them, they will not conclude, that the objections raised against the possibility of such cases occurring, as Von Buch has exemplified in his Work on the Canary Islands, rest on too narrow a view of volcanic phenomena, which, in order to be complete and satisfactory, ought to embrace the phenomena observed in Equinoctial America, as well as those of Europe; the extinct volcanos of Auvergne, as well as the recent ones of Naples and Sicily; and which, at least, should admit of being applied to all cases of upheaving, whether occurring in primary ranges of mountains, in the so called valleys of elevation existing amongst newer deposits, or in tracts of confessedly igneous origin.

Section 4.

Theory of Volcanic Operations.

Having now treated in succession the different phenomena found to accompany volcanic action in its various phases of intensity, we may, perhaps, be in some degree prepared to estimate the relative probability of the two modes already mentioned, by which its existence has been accounted for.

We say, the relative probability of the two, for after all, there will be few so wedded to either, as not to contemplate, new volcanic phenomena being brought to light, fresh principles in Chemistry becoming recognised, which may give a preference to some third explanation, entirely different from either of the foregoing, seeing, that one of those conditions laid down by Lord Bacon as requisite in order to guarantee our belief in a theory, namely, that the cause assigned should be ascertained to have a real existence, can be predicated neither of the one nor of the other.

We would also remark, that the real question at

* The drawing of the cone and crater of Barren Island, Bay of Bengal, pl. iv. fig. 4. will give some idea of what is here described.

issue between the advocates of the rival theories, stated in its broadest terms, is simply this;—whether the phenomena of volcanos seem to imply a process of oxydation or not; if they do, then our acquaintance with bodies which are kindled by the mere contact of water, enables us to explain the manner in which the process of combustion may originate, its continuance becoming a matter of subsequent consideration; whilst, if the facts before us can be accounted for merely by assuming the presence in the interior of the Globe of a mass of melted matter, we should scarcely be disposed to go further for a solution of them.

Now the progressive refrigeration of a ball of melted matter proceeding from its circumference towards its centre, would doubtless produce something like an imitation of one volcanic phenomenon, namely the emission of lava currents, since the contraction of the crust upon its internal contents would squeeze out from to time, at the points of least resistance, a portion of liquid matter proportionate to the gradual diminution of its capacity.

We may also understand, why the points of least resistance should often be on the coasts or in the depressed portions of continents; why the action of the volcano should in general be intermittent; and why it should continue for centuries without becoming exhausted.

We might also account on this hypothesis for the volumes of carbonic acid emitted, regarding them as resulting from the action of the heat upon the constituents of the limestone rocks placed within the sphere of its operation, and consequently as being unconnected with any process of combustion.

But, on the other hand, this hypothesis does not explain, why volcanos should break out in the middle of the sea, where the pressure must be greater, than it is on continents, intersected as the latter are with caverns and fissures; why it should take place in certain lines of coast only, and not generally, wherever there be low land; and why, fed as they would be from an inexhaustible fountain of liquid matter, they should ever become extinguished, or, at least, continue dormant for no very extended a period, as to convey to us that impression.

Neither does this hypothesis explain the differences that exist between the products of volcanos, which, if derived from the same internal source, ought perhaps to be uniform in their composition and structure.

In conceding, therefore, that the conditions of this hypothesis permit us to explain this phenomenon, it is conceived, that we have gone further than we are strictly warranted in doing; whilst with regard to others more characteristic and essential than even the emission of lava, it leaves us altogether in the dark.

In what manner, for example, will the admission of Cordier's theory enable us to account for the evolution of steam, and of the different gases, which we have seen to be constantly present, or for the consequences of the confinement of these elastic fluids in the interior of the Earth, which manifest themselves, in the explosions that accompany an eruption, or in the upheaving of rocks and the production of earthquakes which we attribute to its operations?

Nor can we be considered guilty of any gratuitous assumption in thus attributing them; for, although the upheaving effects of volcanic action have been by some ascribed merely to the hydrostatic pressure of a mass of lava, which had been forced up to the summit of the crater, yet it is plain, that to have brought it into that position in defiance of the laws of gravity, some powerfully moving force must have been required, and what force can be suggested, at once so probable in itself, and so adequate to the effect brought about, as the evolution of a great body of elastic vapour, the existence of which we are compelled from many other considerations to admit?

Aware probably of the difficulties that suggest themselves to Cordier's theory in this its most simple form, many of those who profess to support it, call into play another principle, namely the action of water, which, making its way to depths where the Earth is supposed to maintain a temperature sufficiently exalted for this purpose, is converted into steam, and thus serves by its elastic force to eject the various heated matters which issue from the orifice.

It must be confessed, that such an addition to the theory supplies us with an explanation of much, which former view of it had overlooked, especially, the situation of volcanos near the sea, their power of upheaving rocks, and in general the expansive force, which constitutes one of their leading features.

Yet even here, unless we suppose some kind of combustion to take place, we are left in the dark, with regard to the evolution of sulphurous acid and of nitrogen gases; and unless we suppose the existence of some principle or other capable of decomposing, as well as of converting into vapour, the water that finds admission, we shall hardly be able to account for the steady and copious emission of hydrogen combined with sulphur, which has been noticed.

It may, indeed, be said, that sulphurous acid would arise from the spontaneous union of sulphur with oxygen, at the high temperature to which it would be subjected, if it existed so deep in the bowels of the Earth; and that several of the commoner metals, such as iron, are capable of decomposing water, and combining with the oxygen of the atmosphere, when subjected to the same heat—whence would result an evolution, both of sulphuretted hydrogen, and of the residuary nitrogen, derived from the atmospheric air admitted.

But when the naturalist is once brought to allow, that combustion of some kind or other makes a part of volcanic operations, he will necessarily look to the products of these latter, in order to satisfy himself, what the materials may have been which have contributed to the effects.

Now we have already seen, that the substances ejected from the crater of a volcano usually consist, in the largest proportion of silex, next of alumina, then of oxide of iron, then lime, and lastly soda or potass.

That the elements of these bodies must, some of them at least, have absorbed oxygen from the atmosphere, during the process by which their fusion has been effected, seems to follow, from the nitrogen disengaged, and the ammoniacal salts sublimed; and if we are thus brought to admit, that a metal so oxidizable as iron may exist in its metallic condition at these depths, what is to hinder us from going one step further, and applying the same supposition to the bases of the earths, and alkalies, thus obtaining a readier solution of the energetic character of those processes, which are adequate to produce the effects we witness?

It has, indeed, been alleged, that the two principal constituents of lava, namely, the bases of silica and alumina, are not highly inflammable. Silicon, when perfectly pure, resists a white heat without uniting with oxygen, and aluminium may be boiled in water without decomposing it But, in the first place, it is rare to

meet with these oxides, without finding them accompanied either with lime or an alkali; and the basis of the former, we have reason, from Davy's experiments, to believe, is highly inflammable; the latter we know to be so.

Secondly, silicon kindles readily if united with a little hydrogen or with carbonate of soda; and aluminium even by itself burns brilliantly when heated to redness, and dissolves with the evolution of hydrogen in very dilute solutions of potass.

There is, therefore, no difficulty in imagining the combustion to be kept up by means of the silicon and aluminium, when once it has been commenced by the action of water, upon the potassium, sodium, or calcium present.

It has also been objected, that hydrogen gas is never emitted from the spiracles of any volcano, as if it were not quite natural, that it should be evolved in union with sulphur, when generated in places so abounding in that material.

That the quantity thus emitted has been enormous, will appear from this consideration alone, namely, that the immense beds of sulphur in Sicily are probably derived from certain submarine solfataras, and that in solfataras the sulphur which is deposited arises, not from the sublimation of that solid, but from the deposition of it by the sulphuretted hydrogen and sulphurous acid disengaged, which, when they come into contact, mutually decompose each other.

It is not clear, also, that hydrogen gas may not be evolved likewise in combination with carbon, and even with phosphorus, since the flame, which has been represented as rising from the ground both during earthquakes and volcanic eruptions, indicates the former; and the bubbling up of gas, through the sea, which inflamed on coming into contact with the air, a phenomenon observed near the Azores, would seem to imply the latter.

At all events, a large proportion of the hydrogen emitted may be presumed to make its appearance in the ammoniacal salts disengaged, and a still larger proportion to be recombined with the oxygen of the atmospheric air present, and to appear as steam.

The above hypothesis has this further recommendation —that it accounts for the intense action, which appears to be kept up in some cases without intermission for a considerable period, although it must be supposed to be taking place in caverns, or confined spaces deep in the bowels of the earth.

Had the combustion been of such a nature, as to give rise only to some gaseous product, such as carbonic acid, the combustion would soon have been suspended, or at least checked, by the predominance of a principle so destructive to flame, as we find to be the case in coal mines that have caught fire. Nor would the result have been different, if sulphur, or even phosphorus, had been the sole materials by which the combustion was maintained, for in either instance an atmosphere would have been produced, in which the further oxydation of these bodies could not have proceeded.

But, supposing the substances inflamed to be metals, which form with oxygen a fixed product, and disengage from water an inflammable principle, as in the case assumed, we can see no reason, why the combustion might not continue for ages with unabated vigour, as is the case in several volcanos.

An objection against our hypothesis has also been sometimes deduced from the mean density of the Earth, which is calculated at five times that of water; and hence it has been concluded, that bodies so light, as potassium and sodium are, cannot make a part of its nucleus.

But we are not obliged to imagine a larger proportion of these alkaline bases to be present, than would be implied by the composition of the lava emitted, and probably we shall find not more than four or five per cent. of potass or soda to exist in the average of volcanic productions.

On the other hand, the specific gravity of the basis of silica, and, probably, also, of that of the other earths which predominate in lava, is sufficiently considerable to warrant the conclusion, that a mass of matter, containing these principles in the proportions indicated, and united with as much metallic iron, as we know to exist in the state of an oxide in the generality of lavas, would form an aggregate possessing an higher specific gravity, than that of the compound resulting from the oxydation of the entire mass.

Let us take, for instance, the analysis given by Dr. Kennedy of the lava from Etna, which he states to consist of

Silica	52	per cent.	× Sp. gr. 2.65	=	127.8
Alumina...	19	per cent.	× Sp. gr. 4.20	=	79.8
Lime......	10	per cent.	× Sp. gr. 3.00	=	30.0
Oxide of iron	15	per cent.	× Sp. gr. 5.00	=	75.0
Soda......	4	per cent.	× Sp. gr. 2.00	=	8.0
	100				320.6

We here find that 100 parts of this lava have a specific gravity equal to 320.6, and consequently that the specific gravity of the mass would be no more than 3.2, supposing it divested of water.

Now let us contrast this with the specific gravity of 100 parts of the metallic principles, which would give rise to a mineral possessing the above chemical composition.

Silica.....	52	contains of base	26	× Sp. gr. 2.0	=	52.0
Alumina ..	19	contains of base	10	× Sp. gr. 2.0	=	20.0
Lime.....	10	contains of base	7	× Sp. gr. 4.0	=	28.0
Oxide of iron	15	contains of base	12	× Sp. gr. 7 8	=	93.6
Soda.....	4	contains of base	3	× Sp. gr. 1.0	=	3.0
	100		58			196.6

Now as 58 — 196 — 100 — 340.

Consequently the specific gravity of the whole would be no less than 3.4. The specific gravity of aluminium appears not to be ascertained, but probably it is not inferior to that of silicon, which sinks in the strongest sulphuric acid, and therefore is more than 1.83.

The theory, therefore, we have been advocating, leaves the question with respect to the cause of the Earth's density just on the same footing as before. Those who are of opinion, that the latter may be explained by the mere condensation of such rocks as are found near the surface, in consequence of the superincumbent weight, as certain metals may be rendered heavier by pressure, are entitled to extend this explanation to the case of the alkaline and earthy bases; whilst those who regard the density of the Earth to be a proof, that some heavier matter must exist below, are not precluded from such a supposition, as our theory implies merely the existence of such a quantity of metallic ingredients, as would be sufficient to produce the materials ejected, leaving the constitution of the remainder just as open to conjecture as it was before.

It is curious, indeed, that whilst some have argued, that the kind of materials found near the surface is

inadequate to account for the density attributed to the Earth in general; others, as the late distinguished Professor Leslie, have contended, that these substances would have their specific gravity so much increased by the enormous pressure, that void internal spaces must be necessarily supposed. On this he has founded his singular hypothesis, that the centre of the Earth is filled only with light, the rarest substance known; an idea, the mere mention of which is sufficient to show, how little we can be justified in rejecting an explanation of facts, merely because it appears to militate against the conjectures, that may be conjured up with regard to the internal condition of our Planet.

Dismissing, therefore, this objection, and leaving to our readers full liberty to form their own conclusions with respect to the internal state of the Globe, granting even to such as contend for it, that an internal fluid mass might give rise to some of the phenomena of volcanos; we conceive, that if the opposite theory can explain other effects, which the above leaves untouched, in addition to those which it elucidates, we are bound by every rule of sound reasoning to allow it the preference.

Now that this is the case, we shall attempt to show, by deducing, from the supposed existence of the alkaline and earthy metalloids at a certain depth in the Earth, the several phenomena of volcanos, in the order in which they present themselves.

Statement of the Theory proposed.

We will suppose, that the nucleus of the Earth, at a depth of three or four miles, either consists of, or contains as a constituent part, combinations of the alkaline and earthy metalloids, as well as of iron and other more common metals, in the proportions indicated by the composition of lava; these being combined, perhaps, with sulphur, and constituting various sulpho-salts. Such bodies are gradually undergoing decomposition, wherever they come into contact with air and water, but, defended by the crust of the Globe, as even a mass of potassium of a certain size may be by a crust of its own oxide, if kept perfectly dry, the chemical action excited goes on too slowly to produce any of its more striking effects, unless the latter of these agents be present in considerable quantity. Hence, under our continents, the elastic fluids generated, and the heat evolved, show themselves principally, in their influence on the temperature of the interior, or in the phenomena of thermal waters.

But under the sea, or in any other situation where the pressure of an equally large column of superincumbent fluid assists in forcing the water though the crevices of the subjacent rocks, the action must often go on more rapidly, and the effects consequently wear a more formidable aspect.

These latter, however, will occur in the middle of the sea less generally than on the coast, because the pressure of the Ocean itself furnishes an impediment to the escape of elastic fluids, greater than that of the contiguous land, and they will in general not be constant but intermittent, because the heat generated by the process itself will have a tendency to close the orifice by which the water entered, first, by injecting the fluid lava into the fissure, and secondly, by causing a general expansion of the rock; nor will the water again find admission, until, owing to the cessation of the process, the rock becomes cool, and consequently again contracts nearly to its original dimensions.

Now the first effect of the action of water upon the alkaline and earthy metalloids would be, the production of a large volume of hydrogen, which will either combine with oxygen (supposing atmospheric air to be present) or with sulphur, both being at the high temperature favourable to their union. In the former case, nitrogen gas will be given off, and this, expanded by the heat, will rise towards the surface, either in its free state, or combined with a portion of the hydrogen in the form of ammonia, which, however, will be neutralized by the free muriatic acid, the strongest usually present. Hence the sal ammoniac, so frequently found in volcanos, and the nitrogen given off in hot springs.

The hydrogen not thus disposed of, combining with the sulphur, will form sulphuretted hydrogen gas, which, for the same reason, will rise upwards in a gaseous form, unless it be decomposed by union with oxygen, or in any other way.

But so long as oxygen be present, in sufficient quantity to combine with the hydrogen, and re-convert it into water, the sulphur will continue in combustion, and consequently sulphurous acid will be predominant amongst the gaseous exhalations emitted from the mouth of the volcano.

So soon, however, as the oxygen is consumed, the hydrogen, no longer entering into combustion, unites with the heated sulphur, and escapes in the form of sulphuretted hydrogen, which consequently, towards the close of the eruption, when the oxygen is expended, will predominate.

As, however, the two gases alluded to mutually decompose each other, the appearance of sulphuretted hydrogen from the mouth indicates, not necessarily the entire absence of sulphurous acid at the place where the process is going on, but its less copious production than before, owing to the more scanty supply of oxygen.

The very circumstance of the reproduction of water, by the mutual decomposition of these two gases, might be the means of keeping up the action in a languid manner for an indefinite period.

The slowness with which lava cools, would cause it to go on giving out, for a considerable time, sufficient heat to the adjoining strata, to communicate to the sulphur the temperature necessary to occasion its combination with oxygen; hence, a certain portion of sulphurous acid would be continually emitted, which, however, would be soon decomposed by the hepatic gas present. The water resulting from this process would percolate into the recesses of the rock, attack any portions of the alkaline and earthy metalloids that might have escaped the original action, and give birth to a fresh volume of hydrogen gas, ready in its turn to dissolve a new portion of sulphur, and thereby to contribute to a repetition of the same phenomena. Thus, no diminution in the quantity of water present on the surface of the Globe need arise from even an endless repetition of volcanic processes, a comparatively small portion of that fluid fulfilling the same office in these great natural laboratories, which a little nitre discharges in an oil of vitriol manufactory; the same water serving over and over again as the carrier of oxygen to whatever metallic matter is capable of decomposing it, just as the nitrous gas generated by the nitre furnishes oxygen to the sulphurous acid, owing to its previous conversion into nitrous acid vapour.

The separation of muriatic acid from the common salt and other muriates present in sea water, is explained on the common principles of chemistry, by the superior affinity exerted by the alkaline base at these high temperatures for the silicious or aluminous earth than for the

acid; and the sublimation of iron, in the state of *fer oligiste*, a protoxide, rather than in that of a peroxide, may have resulted from the deoxydizing property of the sulphuretted hydrogen, at the same time disengaged.

The carbonic acid is probably derived from the action of the heat on the calcareous strata contiguous, and is consequently given off even by volcanos that appear extinct, owing to the long continuance of the heat, or the languid action going on long after the tendency to eruption has ceased.

All the phenomena, in short, which are concomitant upon volcanic action, seem to admit of explanation, if we will only suppose salt-water, and afterwards atmospheric air, to find admittance to cavities in the interior of the Earth, where they can come into contact with the metals, and the earthy or alkaline metalloids, combined with sulphur, there existing; and if it be objected, that the presence of air in the interior of a volcano, in sufficient quantity, seems problematical, we may reply, that as the first effect of the heat would be to produce a softening of the contiguous strata, it must necessarily happen, that the evolution of so large a portion of elastic matter would have the effect of bearing them up to a certain distance round the focus of the volcanic action.

This aperture would undoubtedly be occupied in the first instance by the gases given off by the volcano itself; but the slightest intermittence, or even inequality in the process, would occasion a partial vacuum, which the air of the atmosphere would immediately fill.

We may fortify these conclusions by the authority of Sir H. Davy, who in a *Memoir on the Phenomena of Volcanos*, published in the *Philosophical Transactions for* 1828, remarks, that there was every reason to suppose in Vesuvius the existence of a descending current of air; that the subterranean thunder heard at such great distances underneath the mountain, is almost a demonstration of the existence of great cavities below, filled with aeriform matter; and that the same excavations, which in the active state of the volcano throw out during so great a length of time immense volumes of steam, must, there is every reason to believe, in its quiet state, become filled with atmospheric air.

Hence, perhaps, we may explain a phenomenon that has been noticed during the continuance of an eruption, namely, that of the air being heard to rush through the various spiracles of the mountain, with a loud, and as it is represented, an almost musical sound.

Notwithstanding, therefore, the respect we entertain for the authorities, both in this Country and on the Continent, which, in discussing these two theories, appear to have thrown their weight into the opposite scale, we are still disposed to prefer the chemical one just laid down, to that which, in contradistinction to it, we shall venture to denominate the mechanical one.

Not one of the supporters of the latter view has, so far as our information extends, attempted to do that, which alone can exalt an hypothesis, from the rank of a mere vague suggestion of the fancy, to that of a rational and satisfactory solution of a physical problem: none of them has undertaken the task of taking up, one after the other, the phenomena that have been observed to occur during the different stages of volcanic agency, and showing their respective agreement with the principle laid down at the commencement.

This we have at least endeavoured to accomplish in the foregoing pages; and until the same shall have been effected by the advocates of the rival theory, we must be excused for adopting that view, which, even if less simple, we are at least entitled to consider for the present more adequate to embrace all the conditions of the problem to be solved.

Neither should it be forgotten by those who object to our views, on the ground that the existence of the metallic bases of the earths and alkalies in the interior of the Globe is imaginary, that so likewise is that of their own fundamental postulate—the mass of melted matter in the interior of the Globe which they assume; whilst the high temperature belonging to the crust of the Earth, wherever it is out of reach of atmospheric changes, so far from affording any independent proof of their position, would be an almost necessary consequence of such chemical processes as those in which we suppose volcanic action to originate.

PART II.

DESCRIPTION OF ROCKS, ATTRIBUTED TO VOLCANIC ACTION TAKING PLACE UNDER CIRCUMSTANCES DIFFERENT FROM THOSE BEFORE CONSIDERED.

SECTION 1.

On Trap Rocks.

Introduction.

Having now concluded our intended sketch of the phenomena of existing volcanos, and attempted to explain the causes from which they originate, we have to consider in the next place, the influence which they may have exerted on the condition of our Planet, the rocks that have been produced by their operations, or altered in character and position by their agency.

It is this part of the inquiry, which connects the subject of volcanos with the other investigations of Geology, and renders their study of interest, not merely to the Chemist and the Natural Philosopher, but likewise to all who would attempt to explain the condition, past or present, of the Globe we inhabit.

We shall begin then, by considering the rocks, which, though differing in some respects from those produced by volcanos at the present day, appear to us, nevertheless, to be derived from the same cause acting under somewhat altered circumstances.

There are few parts of the World, that do not offer examples of those rocks, which are comprehended by Geologists under the name of trap, including, as it does in its most extensive signification, on the one hand, basalts, greenstones, syenites, and wacke, and on the other, porphyries with base of felspar or claystone. To each of these general subdivisions are annexed sundry mechanical aggregates, in which pebbles or angular fragments of the rocks above mentioned constitute the prevailing ingredients.

Basalt

The first of these, basalt, appears to be an intimate mixture of compact felspar, either with hornblende, with augite, or with both. It is sometimes of an uniform texture, but more commonly contains imbedded crystals of olivine, augite, felspar, and titaniferous iron ore.

Its decomposition seems to give rise to the substance called wacke, a rock of a dull earthy appearance, and a dark greenish or reddish colour, which, when it admits of being examined, appears to be composed of augite or hornblende, with felspar, altered from the effects of weathering or other causes.

Greenstone.

The rock called greenstone is a granular aggregate of those minerals, which in basalt are so intimately mixed, as to be undistinguishable by the naked eye. It, therefore, consists essentially of felspar, either with augite or with hornblende, but the predominance of one or other of the two latter minerals over the felspar, communicates to the general mass that greenish colour from which its name is derived. Thus the term hornblende includes both the rock denominated diabase, and that called dolerite, by Brongniart; it may also comprehend, in a Geological sense, the hypersthene rocks noticed by Dr. Macculloch in Sky, and other parts of Scotland, where the mineral called hypersthene takes the place of the augite or hornblende which generally belongs to it.

Syenite.

Syenite differs from greenstone rather in the proportion, than in the nature of the minerals that compose it.

It consists essentially of felspar and hornblende, but the greater predominance of felspar imparts to the mass a lighter colour. Quartz is also a frequent ingredient, and mica sometimes occurs imbedded.

Claystone Porphyry.

Syenite, therefore, forms the connecting link between this class of trap rocks and the second, where the basis is either of felspar or claystone, which latter is probably only a more earthy and disintegrated condition of the former mineral, bearing the same relation to compact felspar, which wacke appears to do to basalt. The crystals, which impart to this rock its porphyritic character, are necessarily of felspar, but others are often imbedded, such as quartz, mica, augite, or hornblende. Where the basis is claystone, the rock is called claystone porphyry; where it consists of compact felspar, the name of felspar porphyry is applied to it.

In other cases, it consists of that slaty and splintery species of felspar, denominated clinkstone, and then is usually known by the name of clinkstone porphyry.

More rarely the porphyritic structure is not discernible, in which case the rock is called simply, claystone, compact felspar, or clinkstone, according to the nature of its constitution.

With this, or the foregoing class, are sometimes associated other rocks, which appear, from the analogy of their structure and chemical composition, to have been formed by similar natural processes.

Such are the hypersthene rocks above noticed; and to this same denomination appear to belong the serpentine rocks which occur in primitive, transition, and even in secondary formations. Serpentine seems to consist of an intimate mixture of the mineral termed diallage, with felspar; and, when it occurs in a granular condition, constitutes the gabbro of the Italians, or the euphotide of Brongniart. It, therefore, bears the same relation to the latter, which basalt does to greenstone.

Pitchstone.

Another rock belonging to this series is pitchstone, which either consists wholly of the mineral so denominated, or of a basis of that mineral with crystals of glassy felspar, by which it is rendered porphyritic.

It may, perhaps, be considered, rather as a particular form or condition of felspar or basalt, than as a distinct substance, holding to these minerals a relation similar to that which obsidian does to lava.

There ought, therefore, to be two species of pitchstone, the one associated with basaltic, the other with felspathic traps, but the rock commonly so denominated appears to be allied to the latter.

The above-mentioned rocks are found in two different conditions, distinguished by the presence or absence of cells and cavities; the former may be denominated compact, the latter vesicular; terms, which include the corresponding states in which modern volcanic products also occur. Vesicular traps, however, are almost invariably found with their cavities more or less completely filled up with various crystalline minerals, especially calcareous spar, quartz, the several members of the zeolite family, green earth, &c.; hence they are denominated amygdaloids, a term which, in some Geological Treatises, is used to designate a distinct rock, but which in reality constitutes only a particular state, in which all the rocks of the trap family are occasionally found.

Thus we have, amygdaloidal basalt, amygdaloidal greenstone, amygdaloidal wacke, and, though more rarely, amygdaloidal porphyries.

They are also found in fragments or rolled masses, imbedded in a basis consisting of the earthy variety of basaltic or felspathic trap; in other words, either in wacke or in claystone. These mechanical aggregates are known under the generic name of tuff, being called trap-tuff, when the basis is of wacke, and claystone-tuff when it consists of claystone.

Both of them bear a close analogy to the volcanic tuffs, but differ generally in the degree of their aggregation from the latter, the basis of which, being for the most part a kind of volcanic sand, possesses a looser degree of consistency than that which accompanies trap rocks.

General Characters of the foregoing Rocks.

The above rocks have this peculiarity belonging to them, that they occur in connection with all the formations enumerated in the former part of this Treatise, from the oldest to the most modern, resting on them in irregular tabular masses, occasionally alternating with, and still more commonly intersecting them at various angles.

When circumstanced in either of the two former ways with reference to the accompanying strata, they have been denominated beds, with what propriety will afterwards appear; when disposed in the latter way they are called trap veins or whin dykes; whin being a provincial term, originally employed by the colliers in Northumberland to designate any hard stone, but now introduced into the general language of Geology, for the purpose of indicating a rock, consisting of basalt, greenstone, or wacke, traversing the strata in the manner that has been represented.

We shall consider, in the first place, the general structure of trap rocks, and afterwards, those circumstances which may be regarded as peculiar, either to the one, or other of the forms in which it is found.

Trap rocks, in some one of their different forms, present examples probably of every kind of structure which has elsewhere been observed: examined on the small scale, we remark them amygdaloidal, porphyritic, and granular; examined on the large, we find them in some instances slaty or fissile, as clinkstone, in others

divided into thick tabular masses, as basalt and greenstone frequently are.

Prismatic Structure.

But that which peculiarly distinguishes rocks of the trap family, is the tendency to split into prismatic, or, speaking more generally, polyedral masses, which, though it exists likewise in granitic and a few other species of rocks, is no where so frequent or so well displayed as in these. The columns vary in the number of their sides from three, to six, seven, and even twelve; they are more generally straight, but not unfrequently curved; in size they may be said to vary, from an inch to nine feet in breadth, and from a foot to 300 or more in height. They are sometimes continuous for a considerable space, but at other times are obliquely and irregularly divided by fissures or joints, the convex surface of the one being inserted into a corresponding concavity of the other.

The columns are usually at right angles to the direction of the bed, but not always so; in some instances, indeed, they radiate from a central point, forming clusters of columns without any determinate direction, and still more commonly they are placed so irregularly as to interfere one with the other. Sometimes in the same bed, one portion will be prismatic and the rest amorphous, whilst every intermediate condition, from that of jointed columns possessing an almost architectural regularity, to a total absence of all arrangement, will be perceived.

It has been usual to refer this kind of structure to the contraction, which the mass underwent during its cooling down from a melted state; and there is no doubt, that a prismatic structure may arise from a cause of this kind, as we see exemplified in many modern lavas, and in the shrinking of masses of clay, starch, &c.

But there is one circumstance which seems to prove, that the prismatic form of trap is owing to a different cause; namely, that in many cases the columns approximate so nearly, that not even the blade of a knife can be thrust in between them. Now in every instance in which the same kind of structure is produced by contraction, theory suggests, and experience confirms, the conclusion, that a certain interval would be left between the columnar masses so produced.

Spheroidal Structure.

We must, therefore, look to some other cause for the columnar arrangement of trap, and probably the true solution will be afforded us, by considering another kind of structure noticed as existing in these rocks, namely, the spheroidal or globular. In this kind of structure, the rock is either wholly or in part arranged in balls of various magnitudes. The globular form is very conspicuous in the rock of the Shiant Islands; but according to Dr. Macculloch does not appear to be common. A tendency, however, to this structure is manifested in most trap rocks, by the manner in which they disintegrate, those even which are columnar exfoliating into spheroidal forms when exposed to the weather. Now, it is evident, that a series of globular concretions of trap, placed in close contact, whilst in a pasty condition, or in the state of transition from fusion to solidity, would be by mutual pressure converted into a succession of jointed columns, which, owing to slight differences in the compactness and consequent softness of the several parts of the mass, would rarely be exact in their sizes and in the number of their sides, but would exhibit all those variations, which, in that respect, columnar basalt commonly displays. Neither does it follow, that they may not in some cases have shrunk, after the prismatic form has been communicated to them by mutual compression, since this would begin to operate from the moment they ceased to be liquid; whereas the tendency to contract would continue up to the time at which the rock had sunk to the temperature of the bodies surrounding it.

We conceive, therefore, that the spheroidal structure will be found to be the one most prevalent in rocks of the trap family, and that the prismatic is in general only a consequence of it; the former, indeed, arising from a kind of molecular attraction, which begins to display itself in all melted bodies, from the moment they cease to be absolutely fluid, up to the time at which they become completely solid. Hence, the longer the interval between these two points, the more fully does this disposition operate, as has been shown by Mr. Gregory Watt and others, who have caused the particles of glass, and even of lava, to arrange themselves in spheroidal concretions, by allowing them, after being melted, to return to a state of solidity with sufficient slowness.

Having now considered the general structure of trap rocks, let us next examine the peculiarities belonging to either of the two conditions in which they exist.

Tabular Masses of Trap.

One of the most common forms in which the harder varieties of trap are found, is in large overlying masses, sometimes rising into high mountains, but more generally capping the summits of hills of comparatively low elevation. These latter sometimes would seem to indicate stratification, but this appearance is owing to their division into large tabular masses, which again have a tendency to decompose, in an abrupt manner, at right angles to the seams of the stratification, thus presenting a series of mural precipices, ranging one above the other, from which the term trap, which, in Swedish, signifies a *stair*, has been applied to them.

In other cases they appear to alternate with the rocks of the country, but this appearance is most frequently, though not always, deceptive. Dr. Macculloch has shown, that many veins of trap put on a form so far parallel to the stratification, as, when partially viewed, to possess the semblance of beds. Their true nature may in these cases be determined by finding that the parallelism is not long maintained, but that any one such supposed stratum quits its place to intersect the adjoining and including stratified rock, or sends ramifications through the whole series. (See plate v. fig. 6.)

In a few cases, where deep sections of cliffs afford opportunities for examination, it is found, that irregular masses lie beneath the stratified rocks in some places, just as they surmount them in others; and that, from these also, veins proceed to the surface, or in other directions.

Without, therefore, altogether denying, that alternations of trap rocks with neptunian deposits may occur, a consequence which would necessarily ensue, if successive formations of the former rock had taken place at the bottom of water, which was at the time in the act of producing deposits of clay, limestone, or sand; let us go on to consider the case of veins or dykes, to which class the great majority probably of stratiform masses of trap actually belong.

Dykes of Trap.

These dykes occur of all sizes, from a few inches to twenty or thirty yards in thickness. They extend in

some cases many miles in length, as in the case of the great Cleaveland dyke in the North of England, which has been traced in a direct line more than seventy miles. They seldom ramify, but pursue their primary direction in one continuous line. They are usually intersected by fissures at right angles to their walls, and are thus divided into irregularly prismatic concretions.

They often penetrate rocks belonging to different epochs, and wherever the circumstances of the country allow us to follow them for any distance, have been found connected with some great mass of the same material. From their superior hardness and durability, they generally resist decomposition better than the rocks which they intersect, and consequently stand out above the surface of the ground, like walls of stone, whence, indeed, they are termed dykes: the term wall and dyke being synonymous in North Britain. Their effects upon the contiguous rocks are very remarkable. The latter are often thrown down on one side, and elevated on the other, as if by the forcible intrusion of the trap. The same thing occurs, when two trap dykes cross one another, that which has been shifted being considered as of the greatest antiquity. The contiguous rock is variously altered according to its mineral constitution, If it be limestone, it is often rendered hard and crystalline, like marble; if shale or slate clay, it is turned into a substance resembling flinty slate or porcelain jasper; if sandstone, it is rendered hard, and, in a few cases, prismatic; if it be gneiss, it is converted into a kind of hornstone. (Nigg near Aberdeen.)

But the most striking alteration is observed, where the dyke intersects the coal strata. In some cases (Cleaveland) the substance of the coal in immediate contact with the trap is converted into soot, whilst at a little distance it is reduced to a coke or cinder, wholly destitute of bitumen. The roof immediately over the coal is lined with crystals of sulphur, which may have been sublimed from the coal.

Nevertheless these effects do not appear to be universal, and it sometimes happens, that a dyke will traverse a series of rocks for a vast distance, without in the least affecting them. They are also much more commonly produced by dykes, than by overlying masses of trap, though the case of the Meisner shows, that a similar influence is sometimes exerted even by a bed of greenstone overlying coal.

Origin of Trap Rocks.

Such then are the principal facts that seem agreed upon, with respect to the composition, structure, and position of trap rocks; and the conclusion, to which the greater part of them evidently point, is, that they have been produced by igneous action of a kind similar to that, by which volcanic products are forming at the present day.

Their chemical constitution can hardly be held consistent with any other supposition, for they have been found by Kennedy to agree very nearly in this respect with those volcanic products, which they most resemble mineralogically, consisting, like the latter, of compounds of silica, with alumine, lime, and an alkali, commonly potass; substances, which have been never known to enter into chemical union, except under the influence of a high temperature, and have not yet been found as parts of any neptunian deposit, except as rolled masses derived from another quarter.

The general correspondence in mineralogical character, which may be traced betwixt trap and volcanic rocks, is still more conclusive. Thus the basalts of the one find their analogues amongst the augitic lavas of the other; the syenites and greenstones correspond with the greystones or tephrines, and the claystone and felspar porphyry with the trachytes that accompany modern volcanos. We even discover occasionally, in the midst of the products of volcanos, that have been in action since the valleys of the country were excavated, and, therefore, at a recent period, rocks so nearly identical in characters to those which usually are considered as trap, that we cannot deny that the latter are, in fact, produced by volcanic processes. Of this kind are the basaltic colonnades, which occupy the bottom of the valleys in the Vivarais, and have evidently been derived from the volcanic craters above them. The mineralogical and chemical composition, as well as the prismatic structure, of these basalts, are precisely the same as those met with in trap districts; the only distinction that can be perceived being, the presence of void cells or cavities of very minute size, which seldom exist in the older traps without being occupied more or less with crystalline matter.

Neither would it be difficult to find, among the trachytes of Hungary, Auvergne, or the Euganean hills, rocks identical in structure and composition with the porphyries of older date; as, for example, those which accompany the trap rocks at Sandy Brae, in the County of Antrim. The inferences too which an examination of the rocks, placed as it were at the opposite extremities of the series in point of antiquity, could not fail to suggest, are greatly confirmed, by observing the appearances presented by those which belong to an intermediate age. From whatever cause it may have arisen, it is at least certain, that, connected with the deposits belonging to the tertiary periods, is found a class of rocks, which, if regarded as volcanic, seem often to present the characters of trap; and if considered as trap, to put on frequently the characters of recent volcanic products. Such are the formations in the Val di Noto, in Sicily, in several parts of Italy, in Auvergne, in Hungary, and in other parts of Europe, all of which have been traced to one particular period in the history of our Planet; namely, one subsequent to that at which the chalk appears to have been deposited, but antecedent to that in which the Earth was peopled by its present inhabitants.

Nothing, it is clear, could afford a more striking proof of an identity in the origin of trap and volcanic rocks, than this apparent transition from one to the other, in proportion as the circumstances under which they were formed came more and more to resemble those of the present time.

Wernerian Theory with regard to Trap.

Yet, notwithstanding this accumulation of evidence in favour of the community of their origin, it is no long time since the opposite opinion was espoused by some of the most distinguished Geologists in Europe, and a theory, at once clumsy and gratuitous, was invented, for the purpose of explaining, without having recourse to igneous agency, the position occupied by trap rocks, which lie incumbent on whatever stratum might chance to be uppermost.

No doubt, the weight attached to the name of Werner, who was regarded not unjustly as the father of scientific Geology, gave to his views on this subject a currency, which they would not othewise have obtained, but even his authority would not have induced his disciples so

generally to adopt his opinion, had there not been difficulties in the way of the opposite doctrine, which served in some degree as a set-off to the glaring absurdities of their own. We ought indeed, in candour, to suppose, that the Neptunians, as they were called, agreed only in rejecting the volcanic theory of trap as supported by insufficient evidence, and that the majority of them entertained no very decided views with regard to the manner in which it was really formed. Werner, indeed, had called up the ocean to the very summits of the hills, at a period subsequent to the deposition of the other rocks, in order to overspread the Earth with the materials of his newest flœtz trap formation; but his followers must have regarded this merely in the light of an hypothesis, brought forward in order to show, that other possible modes of accounting for the origin of trap might be imagined, without invoking the aid of the God of Fire.

We shall not, therefore, concern ourselves with this hypothesis, to which few probably ever attached implicit confidence, but will merely consider, what was the nature of those difficulties, that induced so respectable a class of Geologists, not very long ago, to withhold their assent from the position, that trap rocks were the volcanic products of an earlier period. In doing this, we shall particularly refer to one only of these rocks, namely, to basalt, conceiving the whole question, as to the formation of other members of the series, to hinge entirely upon the result of our inquiry with respect to this.

Arguments in favour of the Aqueous Origin of Basalt.

The aqueous origin of basalt was asserted, or rather, to speak more correctly, its igneous origin was denied, partly from its relations to other rocks, and partly from its own composition, structure, and position.

It was shown to pass, on the one hand into greenstone, and on the other into wacke, both which substances, it was argued, must have been of aqueous origin; greenstone, because, if it had undergone fusion, the crystals found in it would have been obliterated; wacke, on account of its passage into clay and similar confessedly neptunian deposits.

It was also found to alternate repeatedly with these latter, often without effecting any apparent change in their nature.

The composition of basalt, it was said, contradicts the idea of its having been affected by fire;—it contains water, which does not exist, as had been shown by Kennedy, in the recent lavas most nearly allied to it—it contains various crystals which are fusible at a heat below that at which basalt melts—and it even envelopes masses of limestone, containing all their carbonic acid, and occasionally with their petrifactions uninjured. The structure of basalt is, it was alleged, still more strongly opposed to such an opinion; instead of being vesicular, harsh, and vitreous, like modern lavas, it was compact, stony, and sonorous like iron; instead of being split into irregular, polyedral masses, with wide, intervening spaces, it was often divided into prisms affecting a great degree of regularity, and closely touching each other.

Unlike lavas, it cannot be traced to a crater; nor does it, like them, descend into the bottoms of valleys; but is found often capping hills, whilst it is entirely absent from the low country contiguous.

As to the similarity between basalts and lavas in point of chemical composition, it was argued, that this only proved the latter to have been derived from the fusion of trap, not the former to have been produced by heat themselves.

Shown to be fallacious.

Some of these arguments, no doubt, were founded on a mistaken representation of facts: thus wacke being an earthy kind of trap, and containing the same ingredients as basalt, may be produced in some instances from the disintegration of the latter rock; and when that is the case, its further decomposition would give rise to a rock no wise different from clay. All the cases, probably, in which the passage from basalt to clay has been asserted, fall under this predicament.

The greater number, too, of the cases cited, in which organic remains are said to have been detected in trap, are equally erroneous: the rock in which they are found, being either a trap tuff, as in the Island of Canna; or a wacke, derived, probably, from the decomposition of basalt, as at Joachimstal, in Saxony; or, lastly, a rock altered by the contact of basalt, as the flinty slate of Portrush, near the Giant's Causeway, which contains ammonites.

But, even if basalt had in any instance been found to contain organic remains, this would be no more than has been met with among the ejections of volcanos. Thus, as Mr. Delabeche informs us, in Signor Monticelli's collection of Vesuvian products at Naples, occur fragments of the compact limestones of the district with their organic remains imbedded.

The presence of crystals fusible at a heat below that required by their matrix, offers no objection to the igneous origin of trap, now that it is conceded, that these very crystals may have been produced subsequently, owing to the play of affinities brought about by the fusion of the mass, and operating during the progress of its return to a state of solidity.

Differences between Lava and Basalt explained.

But there are other manifest differences between basalts and lavas, which require to be accounted for, before we allow ourselves to refer the former to volcanic agency; namely, their greater compactness and more stony aspect, the general absence of glassy and of vesicular products, the more regular prismatic structure which they assume, their originating in dykes, and not in craters, and other peculiarities above alluded to.

It remains then to be seen, what were the conditions, which caused the volcanic products of an earlier period to assume an appearance in many respects so different from that which they affect at present.

One circumstance will immediately occur to us, as establishing a distinction between the two cases.

We have seen in the former part of this Treatise, that up to the period of the tertiary formations, the greater part of the Globe, or at least of that portion of it which has come under our observation, was covered to a great depth by water; for, although the formation of beds of coal, the occasional occurrence of fresh water shells, and that of the remains of land animals, convince us, that certain portions of what is now dry land was even at that time elevated above the waters: still it is probable, that these constituted merely detached Islands in the midst of the abyss of ocean; and that the great bulk of our continents were at that period submerged. It follows from this, that the majority of

the trap rocks then formed must have been submarine lavas, and hence we see at once a distinction between the above and those of the present day, which, wherever they are presented to our observation, are necessarily subaereal, or at least consolidated only in shallow water. Thus in the volcanic Island recently produced in the Mediterranean, the products that have come under our notice, are porous and vitreous, like those of Vesuvius; but these, though products of a submarine volcano, have all been ejected into the open air, and, consequently, partake of the character of subaereal lavas.

Effects of Heat modified by Pressure.

This distinction, first pointed out by Dolomieu and Strange, was happily applied by Dr. Hutton, in his celebrated Theory of the Earth, to account for the differences between trap rocks and lavas, on the principle, that the effect of the heat applied would be modified in these two cases, by the influence of the pressure exercised by a superincumbent ocean upon the former, and by the absence of any such pressure on the latter.

"The tendency of an increased pressure," to use the words of his illustrator, Professor Playfair, "on the bodies to which heat was applied, is to restrain the volatility of those parts which otherwise would make their escape, and to force them to endure a more intense action of heat. At a certain depth under the sea, therefore, the power of a very intense heat might be unable to drive off the oily or bituminous parts from the inflammable matter there deposited; so that, when the heat was withdrawn, these principles might be found still united to the earthy and carbonic parts, forming a substance very unlike the residuum obtained after combustion under a pressure no greater than that of the atmosphere. It is in like manner reasonable to believe, that on the application of heat to calcareous bodies under great compression, the carbonic acid would be forced to remain, the generation of quicklime would be prevented, and the whole might be softened, or even completely melted; which last effect, though not deducible from any experiment yet made, is rendered very possible from the analogy of certain phenomena."

These latter anticipations were soon after realized by the masterly experiments undertaken by Sir James Hall, which showed, that the carbonic acid, usually driven off from limestone by the action of heat, may be retained in combination with it by a pressure greatly inferior to that of the present ocean; and that the calcareous matter under such circumstances enters into fusion at a temperature, which it completely resists when this elastic material is expelled.

Sir James Hall has applied this discovery with great success to the explanation of the calcareous matter occurring in the cavities of amygdaloidal traps, and the water present in those of certain agates existing in the same class of rocks. The same will also account for the greater cellularity which modern lavas possess than the generality of traps, the former, even in the innermost part of the stream, where, owing to the pressure of the superincumbent mass, their density will be greatest, exhibiting a number of minute vesicles, the existence of which serves to distinguish them from ordinary basalt.

Not that we must suppose all trap rocks to be destitute of cells, any more than we are warranted in inferring, that all the eruptions that took place at these periods necessarily occurred in deep water.

The existence of amygdaloids, such as are the toadstones of Derbyshire, seems to imply, that the pressure under which certain traps were formed was not sufficient to prevent the disengagement of aeriform fluids; for it is difficult to reconcile this phenomenon to the theory of Sir James Hall, who imagined that such cavities were caused by the infiltration of the crystalline matter, which, when it entered into fusion with the whinstone, kept separate from it, as oil does from water. If this had been the cause of the cavities, they ought to be entirely filled with crystalline matter, which is not the case. Neither is the presence of crystalline matter occupying the cavities a fact absolutely without exceptions. Dr. Macculloch instances the trap of Little Cumbray, in the Kyles of Bute, as consisting of vesicular lava, so light as almost to float on water, having its cells entirely empty, and with a glazed, internal surface, like that of volcanic scoriæ.

But these partial exceptions will not be considered as sufficient to invalidate the general position, that traps are of submarine origin, until some Geologist will either undertake to explain, on some other principle, the differences allowed to subsist between them and lavas, or will point out the inadequacy of Sir James Hall's theory to account for these points of distinction.

Why submarine Lavas cool slowly.

It is true, that the stony aspect of basalt, and the crystalline or granular appearance belonging to greenstone and other members of the trap formation, are less obvious consequences of the principle therein assumed. But it will not be difficult to show, that, although a body of shallow water, from the more rapid cooling it would occasion, was likely to favour the formation of vitreous products even more remarkably, than that exposure to the atmosphere which subaereal lavas undergo; yet deep water would possess the opposite tendency so completely, that we ought to meet among submarine lavas few substances of this description, except where the material had been injected in thin streams into the fissures of a rock, possessing a different temperature, and therefore capable of robbing it of its heat in a more rapid manner.

In order to understand this, we need only recollect, that the cooling agency of water under ordinary circumstances, is owing, not to its being a good conductor of caloric, but to the circulation induced in the strata of that fluid when heat is applied to it.

This circulation is effected in two ways: in some degree, by the heated particles of water at bottom becoming specifically lighter, and consequently displacing those above, but in a still greater degree, owing to the absorption and subsequent disengagement of caloric, caused by the conversion of successive portions of water into steam, and their return to their original condition, when they come into contact with the supernatant liquor.

Now it seems almost a corollary from the laws established by Sir James Hall, and others, that at the bottom of the ocean none of the water could be converted into steam; for if, as this writer infers, the pressure was sufficient to preserve water existing in the very midst of the lava (where the heat must be supposed to be at its maximum) in a liquid form, still more completely would it prevent that, which was incumbent on the heated mass, from assuming a gaseous condition in consequence

of the heat communicated from below. It seems probable, therefore, that, as water is in itself a slow conductor of heat, the cooling of submarine lavas ought to proceed still more leisurely than that of subaereal ones is found to do, and hence that their component parts would remain for a still longer time in that intermediate condition between fluidity and solidity, during which, as Mr. Gregory Watt and others have satisfactorily shown, the particles, released from the controlling power of cohesive attraction, and yet brought within distances favourable to the play of their mutual affinities, enter most readily into new combinations, and assume those crystalline arrangements which are natural to them.

Perhaps, likewise, the superior density of submarine lavas, the general absence of cells, and their not sending forth to the same extent those emanations of gaseous matter which appear to proceed from modern currents, might contribute to the same effect by still further prolonging the period of cooling.

Prismatic Structure accounted for.

The same considerations may explain the prismatic structure belonging to many traps, which we have shown to have resulted from the tendency to form spheroidal concretions, naturally assumed by such rocks on being allowed to cool slowly. Instances of this same structure are stated to occur amongst modern volcanic formations; as by Mr. Scrope, in the interior of the crater of Vesuvius, as displayed in 1822; and by Breislac and others, in the lower portions of a lava bed at Torre del Greco. It is certain, however, that such cases are rare, and that those igneous rocks of recent origin, in which an approach to such a structure is observable, appear for the most part to have derived it rather from the contraction occasioned by sudden cooling, than from the mutual pressure of spheroidal concretions taking place during a more gradual one.

Such are the columns of lava worked into millstones at Niedermennig, near Andernach, which manifest their real origin by gradually approximating more and more, until at a certain depth they become united into one continuous mass. Such also are the rude columns observed near Torre del Greco, belonging to a bed of lava that had flowed into the sea, the result evidently of the rapid cooling thereby occasioned; and in another instance from the same locality, in which, as Professor Lyell observes, "the rock may rather be said to be divided into numerous perpendicular fissures, than to be prismatic, although the same picturesque effect is produced. In the lava currents of Central France, (those of the Vivarais in particular,) the uppermost portion, often forty feet or more in thickness, is an amorphous mass passing downwards into lava, irregularly prismatic; and under this, there is a foundation of regular and vertical columns, in that part of the current which must have cooled most slowly. But the lavas last mentioned are often one hundred feet or more in thickness, and we cannot expect to discover the same phenomenon in the shallow currents of Vesuvius, although it may be looked for in modern streams in Iceland, which exceed even those of ancient France in volume."

Now the greater frequency of prismatic rocks in submarine than in subaereal volcanos is explained, by reflecting, that the slow cooling essential to that structure, which in the latter is accidentally, or in a few cases, brought about by the remarkable thickness of the mass superincumbent, and that only in the lower portions of the bed, is caused in the former throughout, by the vast pressure of the ocean above, whatever may be the supposed thickness of the bed itself.

Greater frequency of Dykes.

With regard to the next point to be considered, namely, the absence of craters, and the greater frequency of dykes in trap rocks, it must be admitted, that we are rather unfavourably circumstanced in order to draw a correct comparison between these and more recent volcanic products in the latter particulars. The craters of submarine volcanos, when composed of loose fragments, would be exactly the portions most likely to have been swept away by the currents of the ocean, or other causes; whilst if they consisted of lavas, they might indeed remain, and yet all vestiges of their original configuration be obliterated by the rocks superimposed.

It would be rash therefore to assert, that craters never have existed, because we do not discover any traces of them at present. On the other hand, it is only where accidental circumstances reveal to us the internal structure of a modern volcano, that we can expect to find dykes, and there we do occasionally meet with them. Thus they are well known to exist on the sides of the old crater of Monte Somma, (see pl. v. fig. 5.) and Professor Lyell has noticed the same in that of Vesuvius at present; these, however, are probably produced by the filling up of open fissures with liquid lava, which had occupied the hollow of the crater, and therefore do not precisely resemble in the mode of their formation those trap dykes which exist in older rocks, the results of an injection of liquid lava into the fissures, through which it made its escape to the surface.

In order fairly to compare together the action of ancient and modern volcanos in this respect, we ought to refer to sections of some modern volcanic mountain, taken at a distance from its crater, of which some of the Lipari Islands afford us good examples, (see Daubeny's *Descriptions of Volcanos*, and pl. v. fig. 1 and 2,) as also does the Val de Bove in Etna, described by Professor Lyell. (See pl. v. fig. 3 and 4.)

There we shall see dykes, which, though mineralogically resembling modern lavas, correspond, in their relation to the contiguous rocks, to the trap dykes described by Dr. Macculloch in his *Western Islands*, as running for a considerable space parallel to the strata, though originating in some great mass of trap underneath. (See pl. v. fig. 6.)

Nevertheless, although it is impossible by a direct appeal to facts to establish beyond the reach of cavil the greater frequency of dykes amongst submarine volcanos, yet probability is certainly in favour of such an assumption.

"If volcanic forces," remarks Professor Sedgwick, "ever have acted on a great scale upon unbroken and nearly horizontal strata, especially while such strata were under the pressure of the sea, the formation of tabular and vertical masses of lava appears a natural consequence of such action. Where, on the contrary, the pressure of the sea is removed, and the crust of the earth is broken through, volcanic fluids will find a ready escape, eruptions of lava will be confined to one spot, and the operations will be of a class altogether different." (Sedgwick's *Geol. of High Teesdale*.)

Trap Rocks, at what Periods formed.

The admission, that trap rocks are lavas, tends very much to enlarge our ideas with respect to the extent of volcanic action at different periods.

From the occurrence of these products in connection with every secondary formation, from the earliest down to the most recent, the chalk, it might be concluded, that volcanic action had taken place during every one of these successive periods; but, except when they can be proved to stand in the relation of beds interposed between the strata, such an inference would not be warranted.

Let us take, for example, the oldest rock with which any considerable mass of trap is associated in Great Britain, namely, the carboniferous system of the Northern Counties, and that in the neighbourhood of Glasgow and Edinburgh.

The former of these, namely the coal field of Northumberland, is associated with many very remarkable dykes, overlying masses, and apparent beds of trap, but the most considerable of the latter, the great whin-sill, which is seen arranged conformably with the carboniferous limestone of Teesdale, and the Northern limestones of Northumberland, has been pronounced by Professor Sedgwick to be in fact a stupendous dyke, or collection of dykes, which has been injected laterally between the strata. He, however, is inclined to refer the injection of this, as well as of the majority of the trap rocks of that neighbourhood, to a period antecedent to the magnesian limestone. Mr. Hutton, and Mr. Phillips of York, differ from the professor in their view of the origin of the whin-sill, regarding it as in great measure formed by periodical submarine eruptions of lava, which took place at intervals during the deposition of the carboniferous strata with which it is associated. In either case, therefore, much of this extensive basaltic formation is allowed to be of a date as ancient as the carboniferous rocks themselves.

The trap rocks of Staffordshire, on the contrary, constitute overlying masses, which may either be contemporaneous with the coal measures on which they rest, or may have been of a date much posterior.

Lastly, the trap rocks near Glasgow are so connected with those of the Western Islands, as the latter again are with those of the County of Antrim, which are posterior to the chalk, that we should be led to assign a much later epoch to their ejection, and likewise, perhaps, to extend the same inference to those in the vicinity of Edinburgh.

Thus we have three cases brought together, in which trap rocks are associated with the same system of rocks; the one of which is of a date antecedent to the magnesian limestone, or at latest contemporaneous with it, the third of the same age as the chalk, and the second doubtful.

In Derbyshire we meet with an apparent alternation of beds of trap called toadstone, which are more generally amygdaloidal, but occasionally compact, with the carboniferous limestone formation. But before we absolutely decided that the two are contemporaneous, it would be necessary to establish more completely than has yet been done, that they are conformable. If this be not the case, they may have been ejected long subsequently.

The most extensive, however, and in all respects the most interesting system of trap rocks, found within the compass of the United Kingdom, is that which occurs in the Western Islands of Scotland, and which appears to be continued on in the County of Antrim, in Ireland. It is interesting, not only from the numerous sections which its situation near the coast supplies, but likewise from the circumstance, that it is not mixed up, as those in other instances are, with the volcanic rocks of an intermediate period, no remnant of the operations which occasioned it being discoverable, either by the existence of hot springs, emanations of carbonic acid, or even earthquakes of any remarkable kind in the contiguous country.

It affords us, therefore, the means of comparing the products of submarine volcanos with those of subaereal ones, and at the same time of inferring, on evidence as conclusive, perhaps, as the subject itself can ever admit of being adduced, that volcanic action has in some instances expended itself, or at least has periods of rest beyond comparison longer in some cases than in others. Now either of these suppositions seems more consistent with the chemical theory, which imagines a definite quantity of combustible materials to be present in particular situations, than with the opposite one, which conceives the existence of an unexhausted fountain of melted matter underneath, such as should either gush out continually, or at least flow at intervals more approaching to regularity.

The trap rocks of the Hebrides manifest themselves under all the forms which have before been alluded to; but it would seem from the observations of Macculloch and others, that the apparent alternations which have been remarked between them and the rocks of the country, are merely caused by dykes intruded laterally between the fissures of the strata. Hence we are only sure, that a considerable part at least of these trap rocks is posterior to the most recent of the strata found associated with them, and the latter appear from the researches of Mr. Murchison to belong to the oolitic series.

But there is no evidence, that they may not be much later; for the basalts of the Giant's Causeway, on the opposite coast of Ireland, intersect the chalk, and are, therefore, posterior to that formation.

It is true, that Dr. Macculloch has shown, from the occurrence of trap nodules in a conglomerate rock of Kerrera, that trap rocks must have been formed at a much earlier period; (*Western Islands*, vol. i. p. 114;) but, as we cannot on any supposition refer the whole to this epoch, we are quite at liberty to adopt any inferences, to which the facts may appear to lead, with respect to the age of the principal portion of that found in the Hebrides.

Perhaps, therefore, the Wernerians were not altogether wrong, in referring the great overlying masses of trap, that they observed in Saxony and elsewhere, to one epoch, and that the most recent, which, in the then existing state of their ignorance with respect to tertiary rocks, they were able to recognise, designating them by the name of the newest flœtz trap formation; for although we may be compelled to acknowledge, that these rocks are of several distinct periods, and that in a great majority of cases their date is uncertain, still it seems by no means improbable, that the most extensive eruptions of submarine volcanos took place about the period just alluded to.

This is rendered more agreeable to analogy, when we remark, that by far the most extensive manifestations of volcanic agency appear to have occurred, either at a period contemporaneous with that to which we have supposed the trap rocks to belong, or at one immediately

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subsequent to it, that is, during the deposition of the different tertiary formations.

It is remarkable, at least, that all the extinct, as well as all the active volcanos, which have been as yet explored, may be traced up to this period, regarding, that is, as we have a right to do, all the volcanic rocks of a district as emanating from the same focus of action.

Thus the lavas of the Val di Noto alternate with rocks which appear to be tertiary; as also do those of Auvergne, of Hungary, of Styria, and of the North of Italy; so that, whether we regard the trap rocks of the Hebrides as contemporaneous with the latter, and attribute their greater compactness to the depth of water under which they were ejected, and from which they may have since been upraised, or whether we prefer to consider them as produced somewhat earlier, still we shall find equal reason for concluding, that during the period comprised between the date of the deposition of the chalk, and that of the creation of the existing races of animals, circumstances were peculiarly favourable to the developement of volcanic operations.

It is remarkable, too, that trachyte, properly so called, seems almost confined to this intermediate period; for although Humboldt speaks doubtfully as to the position of this rock in the New World, yet in the Old, it is found in a number of instances posterior to some of the tertiary rocks, and we know of no instance in which it is decidedly proved to be of greater antiquity, whilst its rarity amongst lavas of modern ejection would seem to show, that it was not, under ordinary circumstances, a product of existing volcanos. Whether this circumstance is to be regarded as the *cause* or the *effect* of that elevation of a large portion of our continents from the sea, which took place at this epoch, it may be difficult to say; but it is certain, that both events may be traced to nearly the same period; and hence we observe amongst the volcanic rocks of this age, that singular intermixture of compact with cellular, of glassy with lithoid lavas, which, at the same time that it affords the most decisive evidence of the igneous origin of trap, indicates the different circumstances under which these rocks were formed; sometimes under the pressure of water, and at other times elevated above it.

Section 2.

On Granitic Rocks.

Various conditions of the production of igneous rocks.

The circumstances under which the germs of igneous energy may be excited to activity, are so various, that even amongst volcanic products poured into the atmosphere, there is great local diversity. If we remember that, for the most part, the phenomena of submarine volcanic action are wholly concealed from our view, we shall be prepared to expect that among the masses formerly produced by it beneath the bed of the sea, and uplifted by subsequent convulsions to the day, many varieties of rocks should be met with, differing very greatly from the products of actual volcanos. As the far greater portion of volcanic effects takes place in the deep parts of the earth, where the rocks remain to be again and again exposed to new influences, it is reasonable to suppose that the products collected from volcanic vents form but a small part of the series.

The subterranean lavas, now in course of production and consolidation, could they be uplifted to the day, would be found very different from the superficial lavas, and far more extensive and abundant. Though, as the preceding section has shown, there be many close analogies between ancient and modern igneous rocks, we ought to expect that the most abundant of these old rocks, while they afford sufficient evidence of their being generated by heat, should appear different from ordinary lava. Granitic rocks are exactly in this case; they are far more abundant than the trap rocks, which most closely imitate volcanic products, and have a different general character. Yet as between superficial and subterranean lava every variety of products may be expected to occur, corresponding to the various conditions, we find between granitic and basaltic rocks so many intermediate varieties, that it is impossible to separate by hard and decisive characters these extremes of the series of old igneous rocks. Basalt is really a volcanic product, in the restricted sense of the word, though not exclusively so; and thus we have from vesicular pumice and glassy obsidian an uninterrupted series of gradually changing aggregations to granite.

Rocks allied to granite.

Granite deviates on the one hand by continual decrease of the magnitude of its particles into very close-grained felspathic rocks, which are greatly analogous to certain kinds of porphyry; on the other, by the substitution of hornblende for mica into syenite. As examples of the latter change, we may instance the syenitic granites of Cruachan and Strontian: the former is illustrated in the granite veins of Arran, and in the fine grained granite of Wastdale and Dufton Pike. (Westmoreland.) In some cases it might, perhaps, be safely admitted, that the same originally fluid mass has been consolidated partly into granite and partly into porphyry, according to the circumstances in which the lapidification happened. In the Valteline granite deviates into hypersthene rock.

General argument.

It would be a mere waste of time to repeat, for the particular case of granite, those arguments, derived from the crystalline aggregation of many minerals never known to be produced from water, but several of which have been fabricated in the furnace, and nearly all are volcanic products, which establish the probability of the igneous origin of the whole class of plutonic rocks. We have shown above that the composition of granite passes by very easy steps to that of rocks whose igneous origin is perfectly unquestionable; if to this we add the fact, of granite entering cracks and fissures in contiguous rocks, as clay slate in Cornwall, hornblende slate in Glen Tilt, gneiss in Cumberland and at Strontian, we shall have said enough in the present advanced state of Geology to secure the admission that granite was generated by heat.

The alternations which in several Countries obtain between granite and some of the older stratified rocks, as mica, schist, gneiss, &c., seem not at all irreconcilable with this view; but they will hereafter, when rightly understood, be found of great value in determining some peculiar conditions of the granitic eruptions.

Peculiar character of granite.

If we seek to understand the circumstances which have impressed upon granite characters so generally distinct from those of the other plutonic rocks, we shall find the following facts important. 1. Granitic rocks usually occur in very large masses below the whole, or a very large part of the whole series of strata, and were evidently formed under the pressure of a great body of water, if not under a pile of superincumbent strata. 2. They are so extensively spread beneath the neptunian rocks as to deserve, perhaps, more than any other, the title of an universal formation. 3. Granite veins, in

proportion to their minuteness and distance from the parent mass, grow continually finer in the grain and more porphyroidal in every respect. This effect is most completely seen along the sides of the veins. 4. In Countries where the great masses of igneous rocks are granitic, as for example Cumberland, the dykes and smaller masses are mostly of porphyry, or of a felspathic quartzose rock, of rather dubious character, which may be called syenite, porphyry, or unmicaceous granite, according to the locality. Such rocks occur about Wastdale head, in St. John's Vale, under Helvellyn, and in High Pike.

On comparing these general facts with Mr. G. Watt's experiments on the aggregation of fused basalt, there appears sufficient ground for believing that the very high crystalline character of granite is owing to its being produced at great depths where it was very slowly cooled to the point of crystallization. We may further venture the hypothesis, that porphyry is merely another state of consolidation of a similar felspathic compound, as trachyte has been supposed to be derived from older porphyries, or even from granite.

Comparison of ancient and modern pyrogenous rocks.

It appears, therefore, that among the older pyrogenous rocks we may distinguish the same two leading groups as among the modern volcanic products, characterised by the prevalence of some kind of felspar in the first, and of augite, hornblende, hypersthene, diallage, or some other analogous generally ferruginous mineral in the second; that in each of these occurs a great variety in the size, distinctness, and aggregation of the crystals, corresponding to the circumstances of the consolidation and differences of composition of the mass. The following short synopsis will express some of these relations among the older rocks.

Plutonic rocks are—1. Felspathic, as granite, porphyritic granite porphyry, amygdaloidal porphyry, claystone, pitchstone.

2. Hornblendo, hypersthenο, &c. { Felspathic, as syenite, hypersthene rock, gabbro, serpentine.

3. Hornblendic, hypersthenic, &c. { As greenstone, basalt, trap porphyry, melaphyre, amygdaloidal traps, wacke.

On reviewing this series, and considering the manner of occurrence of the several members of it, we shall find that the prismatic structure is perhaps more generally developed in the augitic and hornblendic pyrogenous rocks, than in the felspathic branch, and that in both groups the highly crystallized varieties, as granite, syenite, and greenstone, exhibit less of this character than is common to granular claystone and glassy pitchstone, or fine grained basalt and trap porphyry.

Granite veins.

Another thing worthy of notice, is the circumstance that veins proceeding from the mass of a pyrogenous rock into the small cracks and short fissures of a stratified rock are almost peculiar to granite. This phenomenon is hardly ever noticed along the sides of a *dyke* or interposed bed of basalt or porphyry, and is at least very uncommon in connection with even large masses of greenstone. On the contrary, granite is very seldom found in dykes like the augitic and hornblendic rocks, though there is reason to believe that it assumes the form of overlying masses, and alternates in seeming beds with gneiss or mica slate. (S. E. of Ireland, p. 563.)

The variety of interesting considerations connected with granite will justify us in taking a more extended review of its mineral and chemical composition than were necessary while treating of other pyrogenous rocks. Granitic rocks have long been regarded as the source of most of the ingredients of sedimentary strata; a newer theory supposes that granitic rocks are continually forming beneath our feet, in quantities proportioned to the time, by the action of subterranean heat upon the hydrogenous strata. On both of these points some further information concerning the composition of granite will be useful.

Felspar.

Granite is essentially a felspathic rock. Whatever variations happen in respect of the quantity of other ingredients, felspar, in a crystallized state, is universally the basis of granite. In graphic granite the planes of crystallization of the felspar are continuous for great spaces; in porphyritic granite it generally happens that the axes of the prismatic crystals of felspar lie nearly in the same direction; but in common granites it is probable that the crystals of felspar lie in all directions, like the calcareous crystals of primary limestone. The felspar is red, white, green, &c.

Quartz.

Quartz, in a grey, transparent state, more or less evidently crystallized, is almost never absent from granite, but its quantity is very unequal. In graphic granite, quartz, in a sort of interrupted crystallization, is engaged among the laminæ of felspar, so as to assume angular and intersecting figures not unlike the characters of some Oriental language. In the porphyritic granite of Westmoreland the natural faces of the large crystals of felspar are impressed with very small bipyramidal crystals of quartz; and in other granites the quartz may generally, with care, be found crystallized in this form, so as to present on a polished face a regular or elongated hexagonal section. There seems also in some granites a portion of uncrystallized quartz, which is entangled among the other ingredients in irregular shapes. Binary granite, of quartz and felspar only, is seldom met with in Great Britain. It forms part of Muncaster fell in Cumberland.

Mica.

Mica, the third ordinary ingredient in granite, is occasionally very abundant in it; but sometimes absent. It is universally crystallized, generally in regular hexahedral plain laminæ, which enter or cut into the crystals of felspar and quartz, without being themselves interfered with. The direction of the crystals of mica is indeterminate; they do not occur in continuous laminæ, so as to cause the rock to cleave; for though porphyritic granite is in a certain sense cleavable, this arises from the parallelism of the crystalline axes of the felspar. Yet in some Cornish granites we occasionally see the mica aggregated together in a sort of shell, which gives a notion of some kind of lamination, arising perhaps from a limited intestine movement of the mass.

Order of crystallization.

It is generally presumed that the three most common ingredients of granite were crystallized together; by which is meant, that the consolidation of all the crystals was contemporaneous, neither preceding nor following another. This seems not always *exactly* true. In many cases we cannot doubt that mica was crystallized before the other ingredients. If we follow the indications of the penetration of crystalline forms, we shall find in several instances that the figure of the quartz was complete before the felspar was wholly consolidated; and perhaps, adding to this the consideration that the felspar in the solid parts of granite has, in general, only one, and that the primary form of its crystals, while

quartz and mica invariably appear in secondary forms, we may venture to conclude that the felspar was the last crystallized, and, by consequence, has imparted to the mass its most important features. In many large grained granites are cavities, in which free crystallizations of the ingredients occur. In these cases the minerals show themselves in much greater variety of forms, especially the quartz and the felspar. The former assumes variously terminated prismatic forms; the latter is in rhomboids variously modified. (Baveno; Arran.)

Contemporaneous veins.

The aspect of granite is very often diversified by the occurrence of what are called contemporaneous veins; a term which is meant to convey the assertion that the difference of character which it marks was coeval with the formation of the rock. In the large grained granite of Arran and Cornwall, the contemporaneous veins usually appear as long, narrow, ramifying portions of finer grain and a different proportion of ingredients; sometimes with more mica, sometimes with less. The boundaries of these "veins" are indistinct, and the two structures gradually pass into one another.

It will be readily conceived, that a stone composed of crystals so much independent of each other may, especially when the felspar is not very predominant, be very far from solid; it may be very full of minute fissures. These are often clearly enough perceived, sometimes partially filled with small grains of quartz, steatite, felspar, mica, &c. When the stone is by any means subjected to decomposition, the several crystallized ingredients easily separate along these opening cracks.

Imbedded minerals.

It is almost unnecessary to enumerate the various other minerals which are disseminated in granite, except for the purpose of showing how many minerals may be developed from the same fundamental fluid mass. As all of them are *definite* compounds of certain ingredients, and only one simple earthy substance (quartz) remains as a residuum, it is no wonder they are mostly silicates of earthy substances, and that their relative quantity is very unequal, depending upon the possible atomic combinations which should exactly exhaust all the ingredients except the superfluous quartz.

Silicates. Tourmaline, topaz, zircon, cordierite, epidote, garnet, lepidolite, petalite, triphane, steatite, talc, schorl, hypersthene, hornblende, augite.

Aluminates. Cymophane, beryl, pinite.

Sulphuret of bismuth, sulphuret of molybdenum, tungstate of iron, rutile, oxide of tin, graphite, oxide of iron, &c.

Restricting ourselves to the more common varieties of granite, we may observe, that the difference in the crystallization of the ingredients could not be determined *à priori*, from considerations of the relative fusibility of the minerals; because, in fact, these minerals were all developed from one uniform melted mass, in which the only distinct parts were the elementary substances of silica, alumina, lime, potash, oxide of iron, &c.; and it would depend chiefly upon the relative cohesive forces and chemical attractions of certain proportions of these ingredients what crystals should be first generated. In trinary granite, for example, it may not be that mica and quartz were crystallized before felspar because this latter is the more fusible substance, but because out of the mingled mass of elementary substances the particular combination which constitutes mica was endowed with the highest attractive energy. Mica might be formed out of a melted mass at a temperature very far below that required for its own fusion; this being separated, there would remain a silicated felspar, from which the excess of silica being separated, it might depend upon the state of the mass as to heat, whether both quartz and felspar should crystallize together with mutual penetration, or the former impress the latter.

Elementary composition of granite.

If we assume granite to consist of 20 parts of felspar, 5 parts of quartz, 2 of mica, the fused glass from which, on cooling, these minerals were crystallized, must have contained about

Silica ...	1853	of which	1353	formed felspar and mica, leaving a residuum of silica.
Alumina .	404		104	
Potash ...	282		282	
Lime	10		10	
Ox. iron ..	44		44	
Ox. mang.	3		3	

Had the proporticus of alumina and the metallic oxides been greater, it is probable that more mica would have been formed; had they been less, less mica and more felspar might have resulted; and the proportions of the ingredients might have been such that the mica and felspar might be provided with their constituent potash and other parts, hornblende or augite, or hypersthene, with their lime, magnesia, &c., and a residue of quartz remain.

According to the rate of cooling we might have a large grained or fine grained granite, or a nearly compact rock: if the quantity of felspar was very great, and the cooling rightly proportioned, the mica and quartz might be crystallized in a compact, earthy, or glassy uncrystallized basis. Thus felspar porphyry would be produced from the same ingredients as ordinary granite; and the whole investigation appears to teach us that the mineral characters of pyrogenous rocks depend as much upon the circumstances of their solidification as upon original differences of chemical composition. With this all observations on these rocks fully agree; and it is, therefore, in a right spirit of philosophical generalization that Geologists have now accustomed themselves to view the whole series of plutonic and volcanic products as the varied results of one original mode of calorific action operating under a variety of conditions as to cooling, pressure, limitation of space, and other influential circumstances.

Section 3.

Relative Age and characteristic Phenomena of Pyrogenous Rocks.

Age of plutonic rocks.

Were our inquiries concerning the relative age of plutonic rocks to be answered only by appeal to observation of the phenomena which they present in contact with one another, the research must be abandoned. For they neither show themselves so often in connection, nor display, when in connection, such marks of relative antiquity as to permit us to recognise more than one general truth, *viz.* that granite is very often the oldest and basalt very often the youngest of these rocks. But by studying separately the age of each of these rocks in relation to the strata which adjoin it, we obtain a more extensive and more exact series of determinations concerning the periods when they have been erupted through the consolidated crust of the earth. The importance of these determinations in inductive Geology is so great as to demand a preliminary statement of the mode of reasoning employed in obtaining them.

1. When in any Country a certain class of rocks, as for instance the slate rocks, have been convulsed and thrown

into new positions before the deposition of another set upon them, as for instance the carboniferous rocks, and we find occupying the axis or nucleus of the dislocation a mass of granite, it is certain that such granite is older than the carboniferous system because it was uplifted with the older slates. If, in addition, this granite sends veins through the slate rocks so as to prove that it was uplifted in a melted state, we must infer that it is of more recent origin than those slates; and, in fact, that its antiquity is exactly measured by the date of the convulsion.

Age of plutonic rocks

If there be no veins thrown off from the mass of granite, and no other satisfactory proof of its having been uplifted in a melted state, the age of the igneous rock is indefinable, except by saying that it is older than a given stratified rock. Such a case occurs in the Ord of Caithness. It appears, then, that in any case of convulsion the era of the elevation of the igneous rock is determined by the convulsion, but whether it was actually generated at that time from a melted state, requires other evidence. Now this consolidation from a melted state is what fixes the age of an igneous rock. Granite may, perhaps, have remained melted in the deep parts of the earth through many geological periods, but its age as a rock is counted from the period when its fusion closed.

2. In Derbyshire the carboniferous limestone is interlaminated for great lengths by an igneous rock, (toadstone,) which has evidently been poured out at certain intervals by an ancient submarine volcano while the limestone was in formation. The age of such a rock is fixed by the age of the limestone.

3. The basalt of dykes which pass through certain strata, is, of course, not more ancient than the newest strata divided; if at any point the dyke should be covered by newer strata which are undisturbed by the dislocation accompanying it, we may generally admit that the basalt is older than these strata. Such a case, perhaps, occurs in the dykes of the Durham coal field, which do not penetrate the magnesian limestone.

These instances are sufficient to show the truth of two propositions of general application to this subject.

When igneous rocks accompany convulsions, we can always fix the minimum of their geological antiquity; when they throw off veins or intrude in the shape of dykes, or interpolated beds, among stratified rocks, we are able to assign the maximum of their antiquity.

Guided by these views, and restricting our illustrations as much as possible to the British Isles, we may proceed to describe some of the characteristic phenomena occasioned by the appearance of plutonic rocks, and to fix the eras of their production.

First, we shall describe the general features of a district remarkable for the number of these rocks brought into a small compass and presenting diversified effects, and then select instances proper to make known the characters of each.

We shall take an example of the phenomena of pyrogenous rocks in general from that gem of Huttonian Geology the justly celebrated Island of Arran, an examination of which may be safely pronounced almost indispensable to a complete geological education.

Arran.

General features.

The Island of Arran has been very often described, and by eminent Geologists. Jameson, Macculloch, Necker, Murchison and Sedgewick, Oeynhausen and Von Dechen, have all written ably on the inexhaustible subject of this little world of geological phenomena; and were it not for a reluctance to add to this weighty literature, other voyagers would be unable to restrain themselves from describing some neglected but curious phenomena. The leading features of Arran are its mountainous and truly Alpine scenery in the Northern extremity, and the elevated plateaux of its Southern portion. These latter are generally composed of trap rocks, partly syenite, partly porphyry, partly greenstone, with many dykes of greenstone and pitchstone passing through the red sandstone strata which appear around the coasts. The highest Northern eminences are granitic mountains forming the nucleus of a great conical elevation of slate rocks, which, overlaid by the red sandstone formation, (see p. 609.) form a narrow but unequal zone round the granite. The small size of the Island combined with the elevation of the mountains (nearly 3000 feet) gives to the short glens a very sudden depth, and permits the cliffs to show the great curvatures of strata. Dykes and overlying masses of greenstone, felspathic and trap porphyry, various sorts of claystone and pitch-stone, are seen abundantly both on the Eastern, Western, and Southern coasts; and so perfectly are all the phenomena exhibited, that it is difficult to imagine any space of the same limited extent more worthy of being studied for the purpose of understanding the mutual relations of pyrogenous rocks.

That the granite of this Island was upheaved in a melted state seems sufficiently demonstrated by the fact of its throwing veins through the surrounding slate rocks: this phenomenon may be very well studied at Tornidneon. That its elevation was subsequent to the deposition of the whole red sandstone system seems also proved by the curvatures which these strata have undergone. This would give for the elevation of the granite of Arran a period considerably later than that usually assigned to the principal part of the Highland mountains, and, perhaps, agreeing with the rising of the syenites of Malvern and Charnwood forest.

The granite is, as far as can be known, the oldest pyrogenous rock to be seen in the Island, for it is traversed by dykes of basalt and pitchstone, like those which cross the red sandstones. It is observable, however, that these dykes are most numerous at some distance from the granitic centre. At Corygills, at Lamlash, and Tormore, they are exceedingly abundant in the red sandstone, while in the North-Eastern face of the Island, where that rock is nearer to the granite, fewer dykes appear, and about Loch Ranza the slate is still less divided by them. Perhaps we may venture to add another generalization; *viz.* that these dykes are most abundant beyond the line of violent flexure of the strata from their horizontal position. After measuring with care the directions and breadths, and noting the characters of forty-four dykes, chiefly of greenstone, between Brodick and Lamlash, and also those at Tormore, it did not appear to the writer of this notice that any other dependence of the direction of those dykes upon the local centre of the granitic eruption could be traced.

While in the Eastern side of the Island, about Corygills, the dykes in the red sandstone are chiefly greenstone and basalt, with a sparing admixture of felspathic and porphyritic claystone and pitchstone, those of Tormore, in light coloured sandstone, are chiefly pitchstone, claystone, and trap porphyry. On both sides occur

interposed beds of pitchstone, divided into columns; on the East are overlying greenstones in rude colonnades; on the West trap porphyry columns; on the East the claystone dykes are highly prismatic; on the West occur many interposed beds, and an arched vein of claystone. The pitchstone of the Eastern side is black or green, that of the Western coast often variously coloured and graduating to something like hornstone, or to claystone. It is, in one point, at Tormore, of that concretionary structure which reminds us of some kinds of obsidian and sphærulitic traps.

Alterations of stratified rocks.

The effects of the pyrogenous rocks upon those in contact with them are less striking in Arran than in many other situations. No new minerals are produced in the slate where the granite touches it, nor in the red sandstones where they are bordered by the greenstone dykes. This hardening is very various in degree, and the causes of these differences are not very evident even upon the examination of many cases. The hardening effect is sometimes communicated to the distance of two or three feet into the neighbouring rock, but generally not to more than a few inches. The hardened parts sometimes stand up in narrow crests. Where dykes cross, it has been found that one of the planes of intersection of the greenstone dykes has been marked by the occurrence of a very narrow band of black pitchstone. The base of the pitchstone pillars of the interposed bed in Corygills is softened, where it touches the sandstone below, to a kind of kaolin.

It is impossible to say what was the geological epoch of the pyrogenous eruptions of Arran, further than that they were posterior to the whole red sandstone system there. If this be correctly taken by Murchison and Sedgwick to represent both the old and new red sandstone systems, they are later than most of those known in England, and, for aught we can tell, they may be as modern as the basaltic eruptions of the North of Ireland.

Geographical relation of pyrogenous rocks.

It is remarkable that, amidst all the profusion of greenstones, pitchstone, claystone, and porphyritic dykes, which appear a little remote from the granite, no granite dyke is seen; while in the granite, whose elevation seems to be the local centre of all those exhibitions, no hornblende or augite occurs. That granite and the trap dykes are of different antiquity has been shown before; but it seems also to be implied either, first, that at successive epochs different rocks lay melted under the same localities; second, that the local production of pyrogenous rocks is somehow governed by relations of level or distance, or subject to an obscure reciprocity of position. It seems worth while to follow out this idea. Along the Penine chain, the axis of dislocation shows, at points, granitic and greenstone rocks, but very few mineral veins are wrought. The slopes a little removed from this mountain edge contain many valuable lead mines. The mining district of Shropshire, described by Mr. Murchison, appears related to the greenstone ridge of Corndon nearly in the same way; for though along this axis no mines occur, they abound in a line at a small distance parallel to it. Perhaps to these analogies we may add the instance of the diversified porphyritic masses which run irregularly parallel to, but removed from the granitic axis of Cumbria. Finally, to rise to a greater generalization, Von Buch's views of the relations of the granitic axis of the Alps and the augitic porphyries (melaphyre) along their Southern flanks appear to be decidedly analogous, and there seems at least thus much to be inferred from the points of agreement among these several examples of the relative position of ignigenous rocks, that the elevation of an axis or nucleus of granitic rocks was attended by very numerous fissures at a small distance removed, which, after some geological interval, were filled by rocks of a quite different nature from those which were erupted at the time of the first disturbance.

Granite.

Antiquity of granite.

It might be doubtful whether any granite visible in the British Islands could claim greater antiquity than the upper or graywacke slate rocks, except for the cases of alternating granite and mica slate, quoted from Mr. Weaver, p. 563. The granite of the Cornish chain in some places throws veins into the adjacent clay slates, and generally appears to change very greatly the nature of those rocks, so that we are compelled to rank it as a more modern product. The granites of Cumberland and Westmoreland, and those of the Grampians, if their age be judged of from that of the convulsions accompanying them, and from the veins which they throw off, must be pronounced to be of nearly the same antiquity. In the Island of Arran, the granite seems to be not so old as the red sandstone which overlies the carboniferous limestone; in the Alps it must perhaps be supposed to have been in fusion ever since the tertiary epoch.

Granite veins.

A few years ago granite veins were considered as rare eruptions, but at present it is difficult to find a satisfactory example of any extensive tract of granite, without the occurrence of such ramifications through the neighbouring rocks. They occur in Cornwall, Cumberland, and Arran, in Ben Cruachan, at Strontian, in Glen Tilt, and generally throughout the Highlands. The same is true for the Continent of Europe; and perhaps we may no where find a better example of the elevation of granite in *a solid form*, than that described by Murchison at the Ord of Caithness. This granite, on its Northern flank, supports the old red conglomerate, whilst to the South it occupies a cliff on and near the shore, the verge of which affords a remarkable breccia, compounded from all the beds of the oolitic series that occur on this coast. This breccia of sandstone, shale, and limestone, is tilted off from the granite wherever that rock protrudes upon the shore, whilst the strata are regularly developed where the granite recedes into the interior. No veins or portions of the granite are to be met with in or above the oolitic breccia, which, by its disturbed position, appears to fix the maximum of antiquity of the elevation of the granite not beyond the age of the coralline oolite.

Tornidneon.

The granite veins of Tornidneon in Arran pass from a body of very coarse grained granite through nearly vertical laminæ of dark quartzose clay slate; the line of junction dividing the whole side of a hill. One of the veins encloses fragments of slate, divides itself into branches, which cross the laminæ of slate, cutting off both the quartzose and argillaceous laminæ. The granite becomes much finer grained along the veins, and nearly in proportion to their smallness; so that in the narrowest veins it is nearly compact. Strings of fine grained granite divide the coarser sort. (See pl. vii. fig. 1.) (1826.)

Glen Tilt.

In Glen Tilt, Dr. Macculloch has described numerous and valuable facts of this nature. At the bridge beyond Forest Lodge, granite, hornblende slate, and primary limestone are very curiously associated. Veins of red

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granite here divide the other rocks, and inclose fragments of them. The singular interlacements of the rocks here will be best understood by the sketch, pl. vii. fig. 2, taken on the spot in 1826.

1. Primary limestone laminated by hornblende and red felspar in curved lines or detached masses, round which the laminæ of limestone bend, crossed by granite and red felspar veins.

2. White quartz rock and red felspar crystallized.

3. Felspathic rock, red, with layers of black hornblende.

4. Limestone laminated with felspar.

5. The same with less felspar.

6. Hornblende and felspar in layers.

7. Laminated limestone.

(*a.*) Red felspar vein—a little quartz.

8, 9. Hornblende, with layers, masses, and veins of white quartz, and red felspar, which substances often occur together, making binary granite of very large grain.

10. Limestone, with red granite veins.

11. Limestone, red granite veins, and white *calcareous spar veins, which divide the granite veins.*

12. Red granite, composed of red compact or crystallized felspar, white quartz, and black or grey mica, and incloses hornblende masses which are divided by veins of granite ramifying from the general masses of that rock.

Cornwall. The extremity of Cornwall has long been famous for the great variety of curious phenomena connected with the granite veins which there divide the argillaceous slate, hornblende slate, and greenstone rocks, all included by the miners under the title of killas. So many writers of eminence, both English and foreign, have described and reasoned upon these occurrences, that it is difficult to select from the immense variety. The following is Mr. Majendie's account of the veins at Mousehole, three miles South-West of Penzance. (*Cornwall Geol. Soc. Trans.* vol. i.) "At this period the clay slate ceases, and the granite commences, forming a promontory which runs out in a Southern direction from the central ridge. The slate is of a grey colour; it is in strata nearly horizontal, but having a slight dip to the East; it increases in hardness near the junction. The granite, which is generally coarse and porphyritic from the large imbedded crystals of felspar, becomes here of a finer grain, with black mica and light flesh-red felspar. On the North it laps over the schistus. At this spot numerous granite veins, varying in width from about a foot to less than an inch, pass through the slate; the two principal veins proceed nearly East from the hill above, for more than fifty yards, until they are lost in the sea. One of these, not far from its first appearance, is divided and heaved several feet by a cross vein consisting of quartz intermingled with slate; fragments of slate appear also in the granite veins. The most remarkable vein, after proceeding vertically for some distance, suddenly forms an angle, and continues in a direction nearly horizontal, having slate above and below."

The killas at this place has much the aspect of greenstone, and it appears generally true that the clay slate is much altered in character round all the granites of Cornwall and Devon. (See Mr. De la Beche's *Geological Map, Devon.*) The veins of granite are generally most fine grained towards the walls. Von Oeynhausen and Von Dechen mention three principal veins at Mousehole, one $3\frac{1}{2}$ to 10 feet wide; quartz veins cross the direction of the granite veins, and sometimes divide them and apparently alter their character. Schorl occurs irregularly in the granite, and in some of the quartz veins. In other localities, veins of this mineral present interesting phenomena. The intricate character of the venigenous masses of Mousehole will be best understood by consulting the diagram, pl. vii. fig. 3, copied from the sketch of the distinguished Prussian Geologists above named.

At Cape Cornwall, a granite vein *heaves* a quartz vein in a direction contrary to the general law, stated in page 541. In the Lizard district granite veins divide serpentine.

Felspar Porphyry.

The abundance and variety of felspar porphyry, in great masses on the summit of Ben Nevis, and in the awful valley of Glen Coe, is familiar to every traveller in the Highlands; the porphyry of Ben Nevis has been shown by Von Oeynhausen and Von Dechen to have been erupted through the granitic basis of that mountain; the diversified porphyries along the vertical precipices of Glen Coe send veins through the subjacent granites, in number proportioned to the proximity of the situation to the great mass of porphyry. This rock is not columnar; (Macculloch;) it varies through every stage, from claystone to felspar porphyry, the different varieties being sometimes gradually and sometimes suddenly connected. Breccia, composed of fragmented claystones and porphyries, (like those on Ben Nevis, and some in Cumberland,) are often seen in Glen Coe. Ben Nevis.

In the mountain of Cruachan, which overlooks Loch Awe, the hornblendic granite and schist rocks are traversed by a great variety of large felspar and trap porphyry dykes, and some changes of appearance happen to the clay and mica slate, very difficult to be described. Macculloch (*Geol. Trans.* iv.) describes the porphyry dykes as perpendicular, varying from 3 to 50 feet in breadth, traversing alike the schist and the granite veins which divide it, but not in any degree intermingling with either. Dykes of porphyry, of different kinds and colours, may run near or in contact with each other, but in all cases these and other dykes of basalt or trap porphyry are very distinct at the edges, though firmly united to the rock which encloses them. Pl. vii. fig. 4, shows veins of granite traversing the schist of Cruachan, themselves crossed by dykes of two kinds of porphyry. (*Geol. Trans.* iv. pl. vi.)

In the Cumbrian mountains felspar porphyries occur in many situations, and with a great diversity of character; some have a basis of translucent grey or green felspar, and included crystals of glassy felspar and quartz; others are composed of a red, opaque, granular felspar basis, and red felspar and quartz crystals; the basis of others is compact felspar or hornstone, and some have a dark but not basaltic base, with small white opaque felspar crystals. Most of them, like the amygdaloids and greenstones of the same region, occur in overlying masses as well as dykes, but real alternations of them with the slates can hardly be substantiated. They seem to have a Geographical dependence on the foci of granitic eruption, of a peculiar kind. They are not abundant in or *very* near to the granite of Wastdale, Skiddaw, or Shap, but they occur at small distances from each of those masses. The Valley of St. John's shows pale red felspar porphyry overlying slate, well crystallized red porphyry in Armboth fell, and various Cumbrian mountains.

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kinds of felspathic rocks under Helvellyn. Dykes of variable greenish porphyry divide the slates of High Pike, and a solitary red dyke ranges East and West of the granite of Shap fells. No porphyry occurs very far from the granites.

In North Wales felspathic porphyries appear so connected by alternate bedding with the slates, as to have been subjected to the same elevations and undulations of dip; and thus not only prove their high antiquity, but also suggest views as to the frequent recurrence of igneous action at the same points of the ancient bed of the sea during the period of the primary slates.

Cornwall. Consistently with our views of the origin of the crystallized rocks, we may perhaps be right in believing that all the complicated, wholly or partially, crystallized rocks, composed of felspar, quartz, and mica, which are included between and which traverse the real slaty rocks of Cornwall, are either the result of submarine eruptions during the formation of the slate; of the subsequent action of the heated granitic masses upon the killas; of posterior eruptions of melted rock into fissures caused by convulsion, or of some gradual conversion and transfer of mineral ingredients, such as we know to have occurred

It is hazardous to reason on phenomena so remarkable as those of Cornwall, without reference to other districts; nothing but prejudice or indolence will permit Geologists, acquainted with other districts, to neglect the singular and curious facts connected with the Devonshire and Cornish chain. We may freely admit that they, in some cases, point to agencies not yet familiar to our philosophy; that a full examination of the whole series of granites, porphyries, serpentines, and killas, and of the disseminated and venigenous minerals in them, will kindle a brilliant light in the most secret laboratory of Nature; but one thing is wanting, an exact description of *all the characteristic facts observable in each particular case*, without the adornment of theory, or the disarray of new nomenclature. (See Conybeare, Buckland, and Sedgwick, *Geol. Trans.*; the *Trans. of Cornish Geol. Soc.*; and Dr. Boase's recent volume.)

Syenite.

Malvern. The syenite of Malvern is not older than the old red sandstone, which it throws off from its slopes and penetrates by a lateral extension or dyke, nor so young as the new red sandstone which lies level at its feet; the same limits of age must be assigned to the similar rocks of Charnwood forest, which appear under very analogous circumstances. The partially syenitic rocks of Carrock fell in Cumberland, may, very probably, be older. We shall not assign this name to the variable rock of Red Pike and Scale Force: according to Weiss, the syenite of Weinbola near Meissen is superimposed on the green sand system. The Malvern hills, long since described with much ability by Mr. Horner, and a dyke apparently dependent on them lately investigated by Mr. Murchison, will serve to illustrate the phenomena attending syenitic extrusions.

The picturesque chain of the Malverns rises at its centre to 1444 feet above the sea, and looks down over a vast and beautiful region. On the Eastern side the descent is abrupt to plains of horizontal new red sandstone, on the Western more gradual and diversified by ranges of woody hills whose bearing is parallel to that of the chain. Beyond are the slate mountains of Wales. Many small narrow valleys run to the East across the line of the chain.

The verdant surface of these hills, and the circumstance that the pyrogenous rocks are very much decomposed and fissured near the surface, prevents very frequent observation. The great mass of the rocks is of a syenitic rather than granitic character, varying, however, much as to the relative proportions of hornblende, mica, and quartz: the felspar is usually red, epidote, magnetic iron, pyrites, and other minerals occur, and the aspect of the rock is sometimes that of greenstone. Veins of granite traverse the neighbouring rocks. Veins of sulphate of barytes, calcareous spar, and epidote, red hematite, &c., occur in the syenitic rocks.

Elevation of strata. The stratified rocks which are dislocated along the line of the Malverns are best seen on the Western slopes, the oldest of them belongs to the fourth group* of the greywacke series of the Welsh border. (See p. 567.) The sandstones of this and the limestones and shales of the superior groups are partly vertical, or partly *overthrown* to the West, so that for some distance to the West the series of strata *appears inverted*, and the really newer rocks come out from under the older. (*Geol. Trans.* vol. i.) Much local confusion and disturbance of declinations accompany these general indications of violent upward heaving along the axis of the chain. Mr. Horner's very judicious reflections on the bearing of the phenomena of the Malvern upon the then prevalent discussion of the Wernerian and Huttonian Theories of Geology, will be perused with great satisfaction and pleasure as anticipating many of the clearest arguments known in the present advanced state of the Science. As the unstratified rocks have been thrown up along a line from North to South, the bearing of the elevated strata ought, in general, to be parallel to that line, and this has been shown to be the case: the force would be greatest at the point where the unstratified rocks burst forth, and accordingly we find the strata there generally vertical, or even thrown back and in some degree inverted.

The same phenomena of inverted strata are observed by Mr. Murchison parallel to the Abberley hills, which are on the prolongation of the Malverns; and we are indebted to him for an interesting notice of a dyke of dark green syenitic rock, at Brockhill near the Teme, composed of hornblende, felspar, and quartz, eight paces wide, directed West 5° North, and East 5° South. The syenitic rock is prismatic at the sides, the prism lying across the dyke, whose walls are formed of old red sandstone, here of a green tinge, and marls. In contact with the dyke and for 20 feet distance the sandstone is hardened, is of a deep purple colour, and has lost its mica; the marls are altered by the diffusion of carbonate of lime through their mass. This dyke is considered as a lateral effect from the great North and South axis of igneous rocks of the Malvern and Abberley hills.

Hypersthene Rock or Hypersthenic Syenite.

Hypersthene rock forms the pinnacled mountains of Cuchullin, part of Carrock fell in Cumberland, certain dykes in Radnorshire, and is not unknown in Cornwall;

* In the *Phil Mag.* for June 1834, Mr. Murchison has published a new arrangement of these groups, in which the second and third groups are united.

it also occurs in Yorkshire in veins passing through the basalt of the carboniferous limestone series. The exhibition of hypersthene rocks in the Valteline has been described by M. Necker.

This rock may be very generally described as a syenite, of which the felspar is pale flesh-colour, white, or greenish, and the hornblende is replaced by hypersthene, either in very distinct, large crystals, or small concretionary masses. In the latter case it can hardly be distinguished from common greenstone. In Cornwall, Radnor, and Cumberland this rock may be admitted to be of later date than the greater part of the slate system; in Yorkshire it is contemporaneous with the great basaltic formation of the carboniferous epoch; in the Isle of Skye it is probably more recent than the oolitic era; in the Alps it forms a part of the mineralogical axis, and may have been thrown up even since almost the whole tertiary strata of the basins of Europe.

The Valteline.

M. Necker, in his account of the Valteline, establishes the fact, that the granitic eminences which rise along the axis of that singular *valley of elevation*, pass by degrees to common syenite, and afterwards to syenite with hypersthene, in large, small, or even minute crystals, of black or green colour, and metallic reflections. The felspar has a violet tinge. The greater and hypersthenic axis of the valley is coincident with the central line of the great chain of the Alps, from South-West to North-East, and the stratified rocks are vertical on each side, for some distance; afterwards they take opposite dips to the North-West and South-East. The order of succession may be stated to be gneiss, mica schist, changing to talcose and chloritic schist and clay slate. Veins of fine grained granite pass through the hypersthenic rocks and through the mica schist, sometimes holding fragments of this latter, and quartz veins with black tourmalines divide the granite.

Skye.

The Cuchullin mountains in Skye, rendered classical by Macculloch's descriptions, surround the desolate lake of Coruisk, a grand amphitheatre of steep and barren rocks, which decompose so little as to yield neither sand nor gravel to the torrents. A great variety of appearances is presented by the mixture of the felspar and hypersthene in these rocks, as to crystallization and colour. In some localities the mass is fine grained, and in others graduates to common syenite or greenstone. Von Oeynhausen and Von Dechen state that the hypersthene rocks pass into compact greenstone; and that the common syenite lies on the hypersthene rock, with an abrupt and distinct junction. One of the most interesting facts connected with this group of rocks is the transmutation of the lias into white granular and compact limestone, where it is in contact with the syenite and trap rocks. This effect happens more constantly at the junction of the lias with syenite than with greenstone or trap; in the latter case it sometimes happens, sometimes not. The hypersthene rock seldom adjoins the lias; where it does, like greenstone or trap, it both intersects and covers it.

Gabbro, Granitone, Euphotide, Diallage Rock, Serpentine.

It is to M. Von Buch that we are indebted for pointing out the importance of the rock, composed of saussurite, or felspar and diallage, called gabbro, or granitone, in Northern Italy. The abundance of serpentine in the Pyrenees, Apennines, and other parts of the South of Europe, has long been remarked. Diallage rocks are equally abundant, often occur in connection with the serpentine, and there is now no doubt as to the fact that these two rocks are very intimately related. Few conclusions of this nature appear better authenticated by observation than the gradation of diallage rock into serpentine, in the Alps, the Apennines, Corsica, and Cornwall. Gabbro has been employed in architecture by the Romans, and by the family of Medicis at Florence. The town of Vienna is said to be paved with it.

Stratification of serpentine.

Generally, observers agree in representing both gabbro and serpentine as unstratified rocks. When portions of them are included between strata of gneiss, mica, schist, &c., they may be viewed as interposed masses. But Macculloch positively affirms that in Unst the stratification, both of diallage rock and of serpentine, is certainly evident; and he compares the cases where no stratification can be traced in the latter to analogous instances in primary limestone. The latter, however, is by far the most abundant case; and perhaps, taking into account the circumstance that in Unst the rocks alternate and graduate into micaceous, chloritic, and argillaceous schists, we may reasonably inquire whether the stratified varieties of diallage and serpentine are not recomposed rocks altered, like some gneiss, by subsequent application of heat.

In the Northern Apennines, Brongniart has remarked the following general order of succession downwards. 1. Serpentine. 2. Diallage rock, in the upper part assuming the aspect of serpentine, (at Rochetta, North of Borghetto, near Spezia,) consisting partly of red crystallized limestone. 3. Jasper rock in thin laminæ. Below these are limestones and marly schists, common in the Apennines. In Monte Ramezzo, North-West of Genoa, the serpentine is placed on limestone and talc schist, the limestone is in thin tortuous beds, and is as it were dissolved with the shining slate and steaschist. The direction of the serpentinous masses in the Northern Apennines, to which the elevation of that part of the range is ascribed, is East South-East, which is the same as that of the Pyrenees, and of some serpentine rocks about Como.

Greenstone.

Scotland has been long and not unjustly considered classic ground for the pyrogenous rocks. We shall take as an example of the occurrence of greenstone, the phenomena in the vicinity of Edinburgh, which have contributed so powerfully to support the philosophical fame of Dr. Hutton. The interesting eminences of Arthur's Seat, Salisbury Craig, the Calton Hill, and Edinburgh Castle, are all composed of trap rocks associated with various sandstones and shales of the carboniferous system, and the labours of Art have added to the admirable exhibitions of Nature.

Salisbury Craig.

In Salisbury Craig is a very fine section of unstratified greenstone enclosed between stratified sandstone, conglomerate, shale, and ironstone nodules, and it is easily seen that both the igneous and sedimentary rocks are altered at their formation. Masses of sandstone and conglomerate, of various forms and magnitudes, are insulated in a confused manner within the greenstone, and portions of greenstone interposed among the sandstones. No dyke appears, but small veins of calcareous spar, occasionally metalliferous, cross the line of junction. The accompanying drawings and references will sufficiently explain the most interesting phenomena observed.

Pl. vii. fig. 5, gives a general view of the face of the cliff, as it appeared to the writer in 1826. The letters of reference, *a*, *b*, *c*, mark points of which details are given below. On a nearer examination, the point *a* shows greenstone gradually changing to a red colour and finer grain near its upper surface, on which rest beds of sandstone, ironstone, and shale, as under.

1. The upper part of a greenstone mass, fine grained and of reddish colour. Veins of calcareous spar, with micaceous iron ore, divide the upper part of this mass, and pass through Nos. 2 and 3 above.

2, 3. Mass of petro-silicious sandstone, mixed with softer green portions.

4. The same sort of hardened sandstone, with less of the softer parts, (here and there a purple tinge.)

5. Argillaceous, compact, hard shale of a purplish or green colour, and subconchoidal fracture.

6. Red argillaceous ironstone in green shale.

7. Sandstone beds, reddish and indurated.

At the point *b* (fig. 6) a nearly similar series of alternating stone and shale rests on very similar trap. A portion of sandstone is engaged in the trap, and other signs of violent intrusion occur.

At the point *c* hard red sandstone flags, without ironstone, rest on reddened greenstone.

A large quarry at the South end of Salisbury Crag affords an excellent section of sandstone beds *below* the greenstone. Fig. 7 and 8 are taken from this quarry.

In fig. 7, the greenstone, reddening below, rests on jasperized sandstone, which is much broken and confused in places; below this is green shale, covering red and white sandstone with conglomerate. Fig. 8 shows portions of sandstone enclosed in the trap, which grows redder towards the contact with the strata below. The aspect of a portion of sandstone fairly enclosed in trap is seen in fig. 9.

Some late observations of Lord Greenock on the appearances presented by a section of the compact greenstone and sandstone strata in the Castle Hill, Edinburgh, show the effect of convulsions acting upon both of those rocks since the eruption of the lithoid lava. At some points of this hill the usual transformations of the sandstones, &c. happen in contact with trap, but in one place beds of sandstone and marl are seen in a state of great disturbance, thrown in angular positions upon tabular greenstone, and not in the slightest degree altered as to hardness or aggregation at the junction. Possibly, the explanation which applies here, *viz.* that the junction of the igneous and stratified rock has been occasioned by convulsive movements, which have lifted them both in a *solid* form, may be found applicable to some other cases in which trap rocks appear to exercise no transforming influence on the contiguous rocks.

Basalt.

The researches of Dr. Berger, Dr. Buckland, and Mr. Conybeare, on the North-East of Ireland, have furnished a highly interesting Memoir in the *Geol. Trans.* vol. iii. from the pen of the latter Geologist. The coast between Belfast Lough and Lough Foyle is one boundary of a large tract reaching Westward to Lough Neagh, and including the river Bann, which is almost wholly occupied on the surface by basaltic rocks rising at intervals to eminences of 1320, 1820, and 1864 feet above the sea. Under this immense overlying mass of basalt are found several members of the English series of strata not known elsewhere in Ireland. 1. Chalk, agreeing with the lower beds of the English series. 2. Mulattoe, an Irish name for the green sand of English Geologists. 3. Lias limestone, (without any other rock of the oolitic system.) 4. Beds of red marl and gypsum salt, resting on variegated sandstone. 5. At the North-Eastern and South-Eastern extremity, coal measures, consisting of red sandstones and shales with inferior coal, appear below all the other strata. The mulattoe and lias are often wanting in the section. The superincumbent basalt is estimated to have an average thickness of 545 feet, (in Benyavenagh it is 900 feet, in Knocklead 980 feet,) and its superficial extent 800 square miles.

The phenomena presented by the basalt, exposed along so great a length of coast, are various and remarkable, and we are not only delighted with the magnificent colonnades of Fairhead, and the geometrical pavement of the Causeway, but instructed by the clear exhibition of the effects of dykes dividing both the congenerous basalt above and the calcareous strata beneath.

The immense mass of trap rocks in this district exhibits, besides basalt, which is the most abundant material, greenstone, clinkstone porphyry, wacke, and red ochre. Near the Causeway, the cliffs, according to Dr. Richardson, consist of alternating basalt and red ochre, in the following order downwards.

1. Basalt rudely columnar, 60 feet.
2. Red ochre or bole, 9 feet.
3. Basalt irregularly prismatic, 60 feet.
4. Columnar basalt, 7 feet.
5. Intermediate between bole and basalt, 8 feet.
6. Coarsely columnar basalt, 10 feet.
7. Columnar basalt, the upper range of pillars at Bengore Head, 54 feet.
8. Irregularly prismatic basalt. In this bed the wacke and wood coal of Port Noffer are situated, 54 feet.
9. Columnar basalt, forming the Causeway by its intersection with the plane of the sea, 44 feet.
10. Bole or red ochre, 22 feet.

11, 12, 13. Tabular basalt, divided by thin seams of bole, 80 feet.

14, 15, 16. Tabular basalt, occasionally containing zeolite, 80 feet.

The stratified rocks in contact with the trap have undergone remarkable changes in several localities.

At Portrush, the trap (a rudely prismatic greenstone) overlies and perhaps alternates with a flinty slate, which contains numerous impressions of ammonites, belonging to the lias shales. This transformation of lias shale, which reminds us of the more extensive phenomena of the same kind in Savoy, was formerly adduced as an argument for the aqueous origin of basalt! Most of the alterations of stratified rocks on this coast are effected by basaltic dykes, which divide both the overlying masses of trap and the subjacent strata.

At the foot of the hill called Lurgethan, basaltic dykes traverse the red sandstone conglomerate, which is indurated near the contact so as to resemble compact hornstone.

The coal measures, underlying the basalt of Fairhead, are crossed by dykes which have changed the ordinary shale into flinty slate, hardened and pyritized the sandstone for 15 yards, and converted the coal to a cinder. The chalk is affected by many dykes to such a degree as to be converted to a real marble, for 10 feet or more from the side of the basalt.

The order of effects is first a yellowish tinge of colour, then a bluish-grey colour and compact texture, then a fine-grained arenaceous aspect, next a saccharine granulation, and finally close to the dyke the chalk is altered to a dark brown crystalline limestone, with flaky crystals as large as those in primary limestone. The flints in the altered chalk assume a grey-yellowish colour; the altered chalk is highly phosphorescent when heated. Examples occur near Belfast, at Glenarm, in Rathlin, and other places. Near the top of the stratum of chalk which crowns the cliffs of Murloch Bay, is an interposed bed of wacke 5 or 6 feet thick. For proofs of local violence accompanying the exhibition of the basalt, and many interesting details, the original Memoirs may be consulted.

The basaltic formation of Upper Teesdale in Yorkshire has been described by Professor Sedgwick, and its continuation through Northumberland by Mr. Hutton; and we can bear witness to the merit of their researches. The great mass of basalt (called Whin Sill) lies in a pseudostratum of most irregular thickness, enclosed among the strata of the carboniferous limestone series, generally in one particular part of the series, so that in the valley of the Tyne its place in the section is constant, and we think it occupies generally the same situation in Teesdale, though in Weardale another layer of basalt occurs. We cannot doubt that it was erupted from several local centres or lines, and that its thickness at different places was affected by their proximity to the eruptive channel. In the short space of six miles, from Caldron Snout to Hilton Beck, its thickness is diminished from 200 or 300 feet to 24 feet, and further South it disappears totally. But to the Northward the range is (interruptedly?) continued to the sea-coast of Dunstanborough.

No dykes pass from this mass (in Teesdale) into the rocks above or below; so that a first view of the case suggests the belief that it was poured out as a mass of submarine lava upon the yet incomplete deposit of the carboniferous limestone. Professor Sedgwick, however, (*Camb. Phil. Trans.*) maintains that it was injected from below amongst these strata, and that it penetrated between the planes of the strata by violently uplifting them.

The strata in contact are affected by the basalt in several ways, which may be well seen about the high force. The subjacent shales are prismatized, so as to be mistaken for basalt, generally much debituminized, so as to become grey or whitened, and rendered brittle by condensation, but not much hardened. The sandstones are in several places highly hardened, rendered brittle and full of fissures, and much whitened. The limestones below the shale are remarkable for having their top bed full of iron pyrites. Those above, but not in contact with the basalt, are for a large tract of country totally changed from a full blue, hard, rather crinoidal limestone in the first degree to a pale blue, crystallized, soft marble, and in the extreme to a loose, granular, saccharoid rock, in which, nevertheless, some traces of organic remains (a crinoidal column) remain. But the most remarkable effect is the generation of garnets in the contiguous shale under the basalt of Cronkley scar; a case analogous to the one described in connection with the dykes of Plas Newydd by Professor Henslow. (*Geol. Trans.*)

The igneous rocks themselves are chiefly a fine-grained dark basalt, changing to a coarse-grained variety of the same ingredients. Contemporaneous veins of very beautiful hypersthenic and augitic trap pass through the basalt in several points, and it is traversed by a few productive lead veins.

The connection of several very remarkable and extensive basaltic dykes with this great "Whin Sill" is rather assumed than proved. In fact, there is no evidence of any one of these dykes being traced into the Whin Sill, and as some of them pass into the upper coal measures, and one divides magnesian limestone, lias, and oolites, we prefer to consider them of different Ages, though certainly related to the same local centre of igneous expansion. Successive injections of similar igneous rocks, at remote geological intervals, seem to be indicated by the phenomena.

These dykes pass in directions to the East North-East, East South-East, and nearly East, and the lines which they take are so straight through all sorts of rocks, their respective breadths, and the quality of the rock in each, so nearly uniform, though in these particulars they differ from one another, that, considering their extraordinary length, we may safely rank them as amongst the most remarkable phenomena of English Geology. The Cleveland or Cockfield dyke, in particular, ranges for seventy miles through the coal series, (where it chars the coal, hardens the sandstones, and debituminizes the shales,) the magnesian limestone, the lias shales and sandstones of the oolite series, which are affected like the coal system below. Generally it is a nearly vertical dyke, but at Cockfield fell is subject to oblique expansions of a singular kind.

The dyke which passes East North-East is remarkable for having a small vein of lead ore running by the South-East side of it, and for converting the shales through which it passes to the state of a soft, whitish shale, called pencil bed, like those in connection with the Whin Sill. It does not cut through the magnesian limestone.

Melaphyre, Pyroxenic Porphyry.

The history of this rock, which has a base of augite or pyroxene, holding crystals of felspar, is indissolubly associated with the name of Leopold Von Buch, who, by a series of observations, chiefly founded on a survey of the Southern flank of the Alps, has been led to form the remarkable opinions: 1. that the elevation of the Eastern range of the Alps, since the tertiary epoch, was contemporaneous with and dependent on the eruption of melaphyre; 2. that the dolomites of the Alps were produced from ordinary limestone at the same time and with the same dependence. The line of dolomites and melaphyres extends (interruptedly) from Bleiberg to Lake Lugano; but the occurrence of so many masses of dolomitic limestone in other situations than where melaphyre shows itself, must render inconclusive the inferences drawn from their connection in the Alps. Neither is this connection always very evident. On the contrary, even at Lugano, it is rather *near* the augitic rock than in contact with it that the limestone is dolomitized. Von Buch's own Map and sections (*Ann. des Sci. Nat.* tom. xviii. pl. vii.) would hardly lead to the opinion that the dolomitization of the limestone was especially due to the presence of melaphyre. For between the dolomite and melaphyre of the peninsula of Lugano, mica schist and another kind of porphyry intervene; and on Monte Argentera, the limestone which

lies upon the melaphyre is not dolomitized. De Beaumont admits that it is even rare to find the dolomites near Lugano in actual contact with melaphyre.

It would, however, be unjust to Von Buch to reject the hypothesis on this account. He himself says it is to gaseous eruptions accompanying the pyroxenic eruption that we must ascribe the alterations of rocks.

The influence of these exhalations might be felt far from the main fissures occupied by melaphyre, and De Beaumont generalizes the phenemena so as to refer the production of dolomite to the exterior line of fracture of the primary rocks; that is, to the line which now divides the undisturbed from the disturbed rocks. See page 761.

The view is thus entirely changed, and certainly rendered more philosophical. Whatever may be its fate in this amended form, Geologists will have been taught by it to investigate generally what connection there may be between certain phenomena of alteration of rocks, certain lines of disturbance, and particular erupted mineral aggregates; and thus the field of research into the conditions of the local metamorphism of stratified rocks is greatly widened, and brought into nearer relation with the speculations concerning general alterations of the primary strata around granitic nuclei and axes of elevation.

Claystone.

In the cliffs of Corygills (Arran) are several claystone dykes. One of these slopes at a considerable angle through the sandstone cliff, and, being very wide, shows a columnar structure in the middle rectangled to the plane of the dyke; along the sides it is slaty. Between the columnar porphyry of Drumadoon and the Coves on the West side of Arran may be seen no less than five interpositions of claystone among the sandstone strata, mostly exhibiting a rude prismatic structure.

Near Tormore is the celebrated arched vein or dyke of claystone represented by Macculloch, and considered as composed of ellipsoidal concretionary layers by Boué. It is redder and softer in the middle than at the sides; it divides strata of red clay and white sandstone. Great variety of claystones occurs in the Pentland hills. (Professor Jameson, *Wern. Trans.* vol. ii.)

Claystone Porphyry.

Trachytic porphyry, (Boué,) clay porphyry, as it is termed by Jameson, occurs on the Western shore of the Island of Arran in considerable variety. It appears in the cliffs in huge overlying masses, and on the sandstone shores in dykes of great width. At Drumadoon many interesting exhibitions of it occur. We extract the following brief notices from a journal of observations in 1826.

A dyke (*a*) of clay porphyry 20 feet wide, ranging South 40° West, includes large modified felspar crystals, which are sometimes nodular in external figure. On the South-East side is a contiguous vein of greenstone. The porphyry encloses masses of greenstone; it is not prismatic. A huge mass (*b*) of clay porphyry, like a dyke or rather interposed bed, dipping South, has on the South a layer of more basaltic aspect, the two being united in one specimen. In the fine range of clay porphyry columns at Drumadoon, which are 60 or 80 feet high, occurs a dyke of greenstone passing in a line of double flexure obliquely through the pillars. At the base of these columns is a layer of more decidedly basaltic rock with few crystals of felspar, through which the same prismatic structure passes. Towards this great mass the dyke (*a*) tends, and is said to join it. A very wide dyke of clay porphyry, ranging North 60° East, (beyond the Coves,) has greenstone on each side, and also encloses greenstone.

Amygdaloidal Trap.

The Hill of Kinnoul, one of the most remarkable masses of trap rock in Scotland, rises near Perth, from out of the great area of red sandstones which lie against the primary strata of the Highlands. Its height above the plain of the Tay is stated by Macculloch (*Geol. Trans.* vol. iv.) to be 600 feet, and it shows precipitous faces to several quarters. The greater part of the hill consists of an amygdaloidal rock, whose basis varies from well-characterised basalt to wacke. The substances which impart to the rock its amygdaloidal character are, green earth, calcareous spar, quartz, and calcedony. Green earth, or chlorite, occurs in nodules generally small and round; it also invests the roundish nodules of calcareous spar, which are crystallized within but externally accommodated to the shape of the cavity in the rock, or to the crystals of quartz which sometimes line the cavity. The spar is sometimes crystallized at liberty in a cavity of quartz or agate.

The quartz is found to vary by several shades into agate and calcedony, which latter sometimes appears in a stalactitical form hanging downwards in the cavities of the amygdaloid. Alternating zones of quartz and calcedony sometimes appear in the same nodule; amethystine quartz also occurs, and we have in Kinnoul almost every variety of angularly zoned agates. Veins as well as nodules of calcareous spar and quartz divide the rock, and more rarely sulphate of barytes, chert, and agate. Veins of heliotrope have also been found, but without the red spots. Macculloch thinks there is not the least reason to doubt that the substances now filling the cavities of the amygdaloid have been introduced at some period since the cavernous aggregation of that rock from a state of lava.

Shales and sandstones are hardened and altered, and much confused at their junction with the trap. A remarkable case of seeming prolongation of thin masses of the shale into the substance of the trap, so as to resemble veins, is described and represented by Macculloch. (*Geol. Trans.* vol. iv. pl. xi.) In these seeming veins the laminated texture of the schist disappears.

Alternations of amygdaloid and sandstone are frequent about Oban.

Wacke.

Respecting this softest of the trap rocks we shall only observe, that in the Calton Hill, Edinburgh, it forms part of those variable masses, which sometimes may be called amygdaloid, sometimes porphyry, and not unfrequently assume the aspect of breccia; being likewise traversed by numerous small veins or strings of calcareous spar. In the superior and Eastern parts of this hill wacke alternates with bituminous shale and nodules of argillaceous ironstone, in many repeated strata dipping to the East. At the surfaces of junction there sometimes appears a gradation from one rock to

the other; and it does not appear that any decided marks here occur of the action of heat upon the shales.

Pitchstone.

As before observed, pitchstone occurs in the Isle of Arran both in dykes and interposed beds among the sandstone strata. The Western coast is particularly interesting in this respect. The same cliffs which exhibit so many claystone masses alternating with sandstone, contain also parallel short bands of pitchstone probably connected with the neighbouring dykes. One of these dykes, about 30 feet wide, is curiously mixed with hornstone, and for the most part bordered along the sides by greenstone. The disposition of these substances in the fissure will be understood by reference to the horizontal plan, pl. vii. fig. 10, where the letters H, P, and G are placed against the hornstone, pitchstone, and greenstone, respectively. The pitchstone is generally of a dark green colour, fissured longitudinally into rude prisms, which are jointed transversely at about two feet distance, or concreted into smooth conical masses. It seems to pass gradually into the hornstone, which is laminated parallel to its bounding surfaces. The dyke appears in one place to deviate from its vertical course and to go under a portion of the sandstone. A greenstone dyke, which is nearly right angled to the course of the pitchstone, is shifted by it.

In another dyke, one side is yellow pitchstone closely approximating to claystone, within this light green and red stripy pitchstone, then silicious splintery stone in irregular masses, (hornstone,) and the opposite side is greenstone. Another of these curious dykes is green pitchstone on each side, then red pitchstone, and in the middle dark grey hornstone.

The pitchstone bed at Corygills is 15 feet thick, and a dark green or black rock, enclosed between strata of sandstone, which are hardened towards the junction. The pitchstone is marked by lines parallel to its nearly level surfaces, and these are crossed by the smooth distant vertical faces of prisms. The lower part is porous; between it and the sandstone beneath is a white crumbly or fragmentary mass soft as steatite, which it much resembles.

Trap Tuff.

Porphyritic Breccia. "Volcanic Sandstone."

Re-aggregations of the disintegrated or fragmented materials of trap rocks are generally known under the vague name of trap tuff and compared with volcanic tuff, sometimes without much reason. Amongst the slaty rocks of Cumbria, in Glen Coe and Ben Nevis, fragments of felspathic and porphyritic rocks are frequently found united into a solid breccia; under Arthur's Seat and in the Calton Hill recomposed irregular strata, chiefly derived from fragmented rocks of igneous origin, appear associated with ordinary greenstones, porphyries, and basalts. In many instances these have no just claim to be ranked with the pyrogenous rocks, but should be transferred to the class of tumultuary and local aqueous deposits: the circumstance that the principal portion of the ingredients is of *igneous origin*, is not probably confined to these rocks, but is often, perhaps with truth, ascribed to the whole mass of sedimentary deposits from water.

In the vicinity of Oban, in juxtaposition with some interesting amygdaloids and altered shales, sandstone beds, composed of the grains of disintegrated trap rocks, are found resting on conglomerate, amongst whose pebbles are granite, porphyry, quartz, red and white amygdaloid, fine-grained basaltic trap, sandstone, jasper, &c.

Mr. Murchison has recently found, along the South Wales border, many examples of the occurrence of sandstone composed of the ingredients of trap rocks. A little removed from the steep slopes of the Wrekin and Caer Caradoc, rocks of this kind occur in beds, and contain organic remains, but in all respects of composition strongly resemble greenstone. This was noticed by Aikin. At the Southern extremity of the Wrekin, the stone is of a dark green colour, and is evidently composed of the ingredients of greenstone and syenite with a few scales of mica. Near the Caradoc these beds contain much decomposed felspar. They are part of the 4th system, p. 568, of the fossiliferous greywacke of Wales, and are attributed to submarine eruptions of volcanic substances in such a state of disintegration as to mix with the sea water, and be diffused over considerable breadths of the bed of the sea.

Section 4.

Mineral Veins.

The circumstances attending the occurrence of mineral veins in the rocks, their intersections with each other, and the arrangement of their mingled metallic and sparry contents, have been sufficiently studied to ascertain that these valuable elements in the adaptation of our Planet to the wants of its inhabitants have been subjected to a great variety of processes depending possibly on one general law, but greatly modified both in combination and energy by local and periodical conditions. In the vague language of imperfect Science, we say, many *causes*, separate or variously combined, have been concerned in the production of mineral veins; and it is probable that the most advantageous mode of investigating their origin, consists in the attempt to infer from the mass of facts already brought together, what are, respectively, the spheres of action and limits of intensity belonging to the several processes concerned; and afterwards, from a more general contemplation of these processes in their various degrees of combination, rise to a comprehensive notion of their connecting laws and general cause.

This is not the mode usually followed by writers on mineral veins. Neglecting the general fact of the complication of the phenomena, they have been mostly anxious to try their bearing individually, or in mass, upon the perfectly general question of igneous or aqueous agency, and thus nothing was explained. A vast abundance of minute information on veins has been irrecoverably wasted; and the experienced miner laughs at the reasoning of the half-informed Mineralogist, contemptuously rejects his theory of veins, and contents himself with believing that the facts are inexplicable. This dissociation of observers and reasoners is the true cause of the comparatively small advantage which has been derived to Geology from the immense and various mines of the British Isles; on the one hand we have the greatest possible variety of phenomena, on the other the full extent of the resources of chemical and mechanical philosophy, but these have not been combined. If the zoological principles of Geology are better established

and more fertile in deductions than the mineral principles, it is not because our knowledge of organic nature is more advanced than the science which treats of the constitution and agencies of inorganic matter, for the contrary, perhaps, is true, but because in the one case the ancient effects and the modern laws of action have been brought into mutual illustration, in the other deprived of all connection.

In order to prosecute the investigation according to the principles which we have stated to be the best, we must limit our inquiry to those subjects most distinctly connected with metallic accumulations in the rocks. To support inferences concerning the general laws of processes which have produced mineral veins, we may with great advantage include the history of basaltic and granitic, and porphyritic dykes, but for the discovery and estimating of the processes themselves only those effects must be examined in which they are especially concerned.

Though in some instances the distinction between rock dykes and mineral veins be imaginary, they are in general clearly contrasted by the nature of the substances which they contain: in the former case, crystallized minerals of the same kind as those great interior masses of consolidated rock from which they often are evidently ramifications; in the latter metallic substances which are not known to exist in nature except in these situations and in other very similar or distinctly related to them by position, and crystallized or earthy minerals, seldom of the same kind as those which occur in any of the rock dykes. To this general rule quartz is one of the most striking exceptions; yet even in this instance it is remarkable that the quartz of veins is of a very different aspect from that mingled with the ingredients of granitic and trap rocks. We must therefore take the presence of metallic matter and certain nonmetallic substances usually connected therewith, and commonly called veinstuff, as the leading characteristic of the mineral veins whose history we are now to examine, and connect with these all other cases of metallic aggregations or occurrences of the vein-stuff which seem referrible to the same or analogous processes.

This view embraces the following points of research. 1. What substances are found in mineral veins and repositories. 2. The manner of their aggregation or mixture. 3. The situations of their occurrence. 4. The relations between frequency, arrangement and contents of the veins, nature, age, and position of the rocks in which they occur.

Substances in the vein.

What substances, &c. The simple minerals which occur in veins and analogous situations, are far more numerous than those which are found as component parts of the rocks. Igneous rocks, and especially those of modern volcanic origin, hold a very great variety of nonmetallic substances, some of which also occur in veins; but it is almost exclusively in this latter that we are to seek the metals in their pure state, alloyed with one another, or mineralized by combination with sulphur and other combustibles, with oxygen, chlorine, and other gases, or converted into salts by union with various acids. Every elementary substance yet discovered by Chemists exists in the earth, and it is probable that none of these are entirely absent from the solid contents of mineral veins; though this has not yet been shown to be the case for iodine and bromine, which seem universally present in the modern ocean, and azote, which appears in an especial manner devoted to the atmosphere and to the organic portion of nature.

Alloys. The metallic substances seldom occur pure, sometimes in alloys, similar for the most part to those now producible by the Chemist, as silver, antimony, cobalt, nickel, iron, with arsenic; silver and nickel with antimony; lead, gold, silver, and bismuth with tellurium; silver with mercury; platinum with gold, &c. The only known circumstances which stand as antecedents to the production of such alloys, is heat, produced by either chemical or electrical action; and perhaps there is no *single fact* connected with the theory of veins, on which the conclusion of the influence of heat in their production might be more securely based. The rarer occurrence of *pure* metals affords an argument perhaps of less force, but perhaps we may draw the same inference from the very numerous class of metals mineralized by union with combustibles, as sulphur, phosphorus, carbon, selenium, &c., to the formation of which, according to the state of our knowledge of chemical forces, heat would appear to be directly necessary.

Comburets.

Oxides and salts. We cannot apply this general argument to the case of the metallic oxides which are very prevalent in veins, because, in the first place, these are produced under various relations to heat, moisture, and contact with gaseous substances; and, secondly, have various degrees of permanence when exposed to high temperatures, either separately or combined. Neither have we any general conclusion to present concerning metallic salts, which likewise are not rare in veins, since these are also in the same way various in their origin and degree of permanence. There is besides a difficulty attaching to this branch of the subject arising from the interesting fact, that, in very many instances, metallic oxides and salts are derivative compounds from sulphurets and other primary combinations; and when this is very evidently the case, they are called epigene. This may be said to be even frequently the case with oxide of iron, carbonate of copper, and probably carbonate, phosphate, and other salts of lead.

Nonmetallic minerals. Besides the metallic ores which impart to many veins their most striking, if not most constant characters, various earthy minerals lie in these repositories, and, as will afterwards appear, under certain definite relations to the enclosing rocks as well as to the included metals, and with a less distinct dependence on the local situation or *mining district.* These earthy substances are usually called the gangue, vein-stuff, or matrix of the ore. Generally they are crystallized, as quartz, fluor spar, calcareous spar, phosphate of lime, the sulphate and carbonate of barytes, strontites, &c.; sometimes appear massive, as quartz and several other minerals when the vein has no cavities in it; and sometimes the vein-stuff is entirely soft argillaceous matter, of different aspect in different mining districts. We are not aware that these soft kinds of vein-stuff have ever been analyzed, though probably some curious results might reward the labour. The Cornish mines would furnish many examples.

Rider. In some veins, masses of the neighbouring rocks are enclosed and penetrated to a great extent by little *strings* of the ore and spar, so as occasionally to be worth the trouble of working. The vein is said in this case to bear a rider. It, in fact, sometimes becomes under these circumstances a double vein: more rarely pebbles

and other marks of watery action, are stated to occur in soft veins.

Mode of Aggregation of the Ingredients.

In this respect there is a variety of appearances which deserve especial notice as indicating some of the conditions under which the vein was filled. In some cases, for instance, the whole breadth of the vein is occupied by one kind of substance, as lead ore, or quartz, or sulphate of barytes; in other instances, the metallic matter is interspersed in small masses through a general basis, as quartz; but, generally, the different substances which fill the vein are ranged in a definite order of succession from the sides of the vein toward the middle, in which, commonly, the metallic matter occurs in an irregular vertical table called a *rib of ore.* These variations are best observed in the proper veins, but are also to be noticed in the *nests* and detached masses of ore and vein-stuff which sometimes occur in the vicinity of the veins.

General idea of mineral vein.

The *ordinary* notion of a mineral vein is well exemplified in some Derbyshire specimens, not rare in collections, which, when cut across, show in the middle masses or a continuous rib of galena, and on each side of this, to the extreme edges of the mass, (or narrow vein,) layers of fluor spar and carbonate of barytes in frequent alternation, all the materials being crystallized together without leaving any cavities, yet preserving their own character of structure.

Thus, in the diagram, pl. vii. fig. 11, *a* is the middle rib of galena, *b b, c c,* the alternating bands of barytic spar and fluor spar; *d d,* the masses of rock which enclose the vein, are called the walls or cheeks of the vein.

Supposed successive deposition of the substances.

The contemplation of these specimens seldom fails to impress upon the mind an imperfect conviction that the several bands of mineral substances were deposited on the cheeks or walls of the vein in succession, the middle being filled last of all; and this theoretical notion has been illustrated by comparing a mineral vein to a narrow gallery whose walls were covered by many successive coats of plaster of different colour and composition. Werner adopted the notion of the unequal antiquity of the vertical layers of the vein so implicitly as to speak of the middle ribs as always of less antiquity. It is difficult to resist this impression, especially when, in addition to the circumstance of the succession of the laminæ, we observe that these laminæ are so crystallized as to turn their free terminations towards the centre of the vein, and in that direction to imprint the next layer with their own forms, just as crystals forming in a vessel shoot their points toward the part still remaining liquid, and in that direction are covered by the subsequently formed crystals. Very similar inferences are suggested by certain agates, and more distinctly by geodes in basalt, and the crystallized cavities in limestones, in the interior of shells, &c.; in which cases the hollow towards which the crystals pointed still remains.

Reasons against this notion.

Yet this first impression loses much of its force when, instead of confining ourselves to a cabinet specimen, we examine the whole extent of a mine; for here in the first place it is very often found that the regular succession of minerals from the side to the centre is a limited though repeated phenomenon; that the rib of ore is of short horizontal, and sometimes still shorter vertical extent, diminishing to nothing, or diffused in small grains through the contiguous spars; that different metals are found in the same vein at different depths and at distant points along its course; and that both the quantity of metal and the presence of spars are dependent on the hardness, and perhaps on some properties imparted by the chemical nature of the rocks which the vein divides. Instances of this will be given hereafter.

Chemical reasons.

The phenomena of crystallization before alluded to can hardly be thought to prove the successive introduction of the mineral laminæ into the vein; though very probably they do demonstrate the order of crystallization of these substances.

In some cases we observe indications that one kind of mineral has been formed round another as a nucleus; as for example, sulphuret of copper round icosaëdral iron pyrites in a part of Caldbeck fells, Cumberland, and more frequently in many places carbonate of copper and carbonate of lead round the sulphurets of those metals. It is very often the case that the metallic matter of the vein is collected into the middle and forms there a distinct tabular mass, called a rib of ore, more rarely it is disseminated in the gangue. Generally, only one kind of metal abounds in the same part of the vein, but the same vein may yield lead above and copper below, copper above and tin below, or lead in one place and copper in another. The observation is frequent that ore is collected into certain vertical portions of a vein which are worked above and below level, and between which little but vein-stuff is found in the horizontal drift. There is a vague notion amongst miners, that veins are most productive in the deep, and it is at least probable that they are less rich near the surface.

Association of minerals.

Werner insists on the fact, that certain associations of minerals can be traced in veins. He notices the concurrence of lead glance, and blende or calamine, and copper pyrites; of cobalt, copper, nickel, and native bismuth; of tin, wolfram, tungsten, molybdena, and arsenical pyrites; of topaz, fluor spar, apatite, schorl, mica, chlorite, and lithomarge; of brown ironstone, black ironstone, manganese, and heavy spar. He says where tin occurs, ores of silver, lead, and cobalt, heavy spar, calcareous spar, and gypsum are rarely found. Cinnabar and other ores of mercury scarcely ever occur with the ores of other metals, except iron ochre and iron pyrites.

Rolled and fragmented masses.

That fragmented masses of the neighbouring rocks should be found in mineral veins, cannot be thought surprising. It is a common occurrence in mining districts, both of primary and secondary rocks. Thus gneiss at Joachimsthal, clay slate in Cornwall, limestone in Cumberland, are included in the veins. A more remarkable case is that of *rolled* masses lying in the veins. Werner mentions a vein in Danielstollen at Joachimsthal, fourteen inches wide, which, at one hundred and eighty fathoms depth, was almost entirely composed of rolled pieces of gneiss, some of them nearly spherical. In the Stoll Kefier, near Riegelsdorf, a vein of cobalt was cut through by another vein of sand and rolled pieces. These examples seem satisfactory, but we must always be careful to discriminate between rolled pebbles and concretionary masses.

General forms of veins.

Mineral veins are usually distinguished by miners into several kinds, according to their general form and direction, because these circumstances are the most influential in the arrangement of their works. *Rake veins,* the most common and characteristic, may be considered to fill long, narrow fissures, which pass in a vertical or highly inclined direction downwards from the surface

through a great thickness of the subjacent rocks, whatever these may be, and preserve nearly the same angle of inclination and the same linear direction through their whole course. *Pipe veins* are also highly inclined, and pass downwards in the same manner, but they rather resemble irregular chimneys than fissures, and are subject to great swellings and contractions of their diameter. They sometimes pass downwards along the surfaces, and in other cases penetrate through the substance of the strata. The mines in the neighbourhood of Ecton, in Staffordshire, are on pipe veins. Perhaps we may give the same name to the irregular cavity of copper ore, which forms the celebrated Parys mine in Anglesea, and to the iron mines of Dannemora, in Sweden. *Flat veins*, or *streaks*, as far as we are acquainted with them, seem hardly to deserve a special name, being only portions of rake veins which have been changed in their inclination, and made to pass for limited distances parallel to the beds. In the limestone districts of the North of England, this happens principally in connection with certain limestone beds. Williams has a title of *Gash veins* to express such as range for considerable lengths, like rake veins, but are wide at top, and grow narrower downwards, till they entirely vanish. This is a rare case; though Werner's opinion seems to be that many veins grow narrower downwards.

Strings.

Perfect parallelism of the sides or walls of a rake vein, which is the most regular of all, is a rare phenomenon. Most commonly, indeed, there is a definite boundary to the mineral masses presented by the rocks on each side, but this is only on the great scale; and the operations of mining disclose to us innumerable cracks and fissures in these boundary walls, which, when filled by metallic or spongy matters, are called strings, and are frequently worth the labour of following even to great distances from the parent vein, if, indeed, we are entitled to use this hypothetical expression. The notion of miners generally appears to be, that these strings are to be viewed as *feeders* of the vein, and in proportion to their frequency in many instances, is the productiveness of the vein. In the accompanying diagram, pl. vii. fig. 12, the vein v, v is represented as sending out small branches or strings into the neighbouring rock. A rock thus penetrated by strings is sometimes said to be *ridered*, just as the masses which are often included in the vein, and the walls which bound it, are called *rider*. In many rocks these ridered parts are very greatly altered from their original state.

It sometimes happens that, in passing through rocks of various hardness, as limestone, shale, &c. the veins turn flat for a short distance on the hardest and most connected beds, (as, for example, on the Tyne bottom limestone of Cumberland,) and afterwards continue their course. These flat parts usually send off strings into the limestone, which may thus be ridered to a considerable distance.

Disseminated veins, &c.

Sometimes the mineral is disseminated through the parts of the rock adjoining a vein, or collected in small nests and other closed cavities. This happens not only in the Cornish mines, in killas and granite, but in those in the mountain limestone tracts of the North of England, and even in magnesian limestone. Generally speaking, we may be sure that this metallic impregnation is so related to the veins, that it is an effect of the same agent. Whatever filled the veins, also transferred to small distances from them some of their constituent minerals. Certain metals and ores are more liable than others to this lateral diffusion. Native silver, silver glance, red silver ore, native copper, tin ore, iron pyrites, and red iron ochre, are specially noted by Werner as occurring in this way. He says, copper ore, pyrites, and lead glance seldom exhibit this effect. The assertion may be disputed as to galena, which is found as well as blende, and bitumen, and calc spar, and quartz, in closed cavities of shells, in mountain limestone, and in other strata.

Tin floors, Stockworks, &c.

The dissemination of tin ores through some of the rocks of Cornwall, is noticed by Mr. Hawkins, under the title of Tin-floors. (*Geol. Soc. of Cornwall Trans.* vol. ii.) He observes, that the whole tenement of Botallack is said to be full of tin floors. At Zinnwald, mineral beds or floors have long been the object of mining adventure. There granite alternates with the tin floors, which consist of quartz and mica, with tin ore, fluor spar, and wolfram, quartz and mica with tin ore, &c. At Breitenbrünn a floor of this kind has been very extensively worked in a gneiss rock.

The stockwork of the German miners is to be considered as a mass of rock impregnated with metallic matters, in numerous small veins, which come together irregularly, so as to make particular parts extremely rich. The working of such mineral repositories is directed by quite other principles than those which serve for straight veins of definite magnitude. The stockwork is generally opened like a vast quarry, and the excavations are prosecuted irregularly in the most favourable directions. Perhaps the copper mine of Parys mountain in Anglesea, the iron mine of Dannemora in Sweden, the tin ore mine of Geyer in Saxony, are examples of immense stockworks. Werner, however, appears to have considered the stockwork as peculiar to tin ores.

Relations of Veins to each other.

The influence which veins exert on each other may be in some measure ascertained by an examination of the phenomena at the points where they come into contact or cross each other. At these points it is very often found that the quantity of ore is suddenly increased to a large amount, and for some distance, either in one or both of the veins. Many veins are productive only near such points, or yield there peculiar ores and minerals. This does not depend upon the enlargement of the vein merely, but is one of many facts which appear to indicate the agency of certain electric attractions in the disposition of the materials of mineral veins. We have heard miners say, that in certain cases neighbouring veins are subject to a kind of reciprocity, so that they are not both productive in the same ground, but where one is rich the other is poor; but this cannot be established without a very large collection of instances carefully observed.

Age of veins.

The intersections of veins likewise furnish us with another well-ascertained class of facts, which throws light on the relative epochs of their production, independent of the evidence on this subject furnished by the rocks which they divide. When two veins cross, it almost invariably happens that one of these cuts is continued right through the other, as a wall is sometimes continuous through another wall of brick from top to bottom. Thus, a vein of copper ore may cross and cut through a vein of tin ore, a vein of lead ore may cut through a vein of copper o.e, and all these be cut through by some other sparry vein or porphyry dyke. It is supposed, by almost every writer on the subject, that the relative an-

tiquity of the veins which thus intersect one another may be immediately determined; and that in every case the vein which is cut through is the oldest of the two. Werner took this as the basis of his classification of veins, and most practical as well as theoretical miners agree in his views; but they are nevertheless controverted upon various grounds, and as the question is of great interest, it will be useful to present a short connected view of the facts bearing upon it.

We cannot make a step in this argument, except upon the admission that the veins are posterior to the rock which encloses them; in other words, that the space in which the mineral masses of a vein lie, once existed as a fissure in the rocks, and was subsequently filled up by the accumulation of the sparry and metallic matters. This is generally supposed by authors to be a self-evident proposition. It is equally allowed by the Wernerian and Huttonian hypotheses; and practical miners can with difficulty be made to understand that any doubt has been entertained on what seems to them so plain a truth.

Phenomena in Cornwall considered.

But the embarrassing phenomena of the granitic and mineral veins in Cornwall have created amongst some of the Geologists of that district a strong suspicion, that veins are not to be pronounced of different antiquity on account of the circumstances of their intersection, nor to be considered as filling fissures at all; but that the veins and the rocks which enclose them are of the same origin. Even the common fact of veins passing through slate into granite, does not appear to them subversive of their views, which would reduce to one epoch and one origin the most dissimilar chemical and mechanical phenomena. This insulated opinion has been generally neglected, as opposed to the actual state of knowledge and inference on the subject, but as it undoubtedly contains at least a portion of truth, we shall trace a few of the circumstances on which it is founded. Those who favour the opinion in question, must not be surprised at our omitting altogether what may perhaps appear to them the strongest argument of the whole, *viz.* the mechanical difficulties attending the generally received view, that veins were originally fissures of the rocks, because these difficulties have been in some cases surmounted, and in the rest are certainly more than balanced by others of a different kind affecting the Cornish theory. It is, besides, no argument for one theory that another is beset by difficulties which are left unexplained in both.

In the neighbourhood of a vein.

1. It is a general fact, that the walls of a vein partake in some degree of its characters, and that effects, apparently depending on the vein, propagate themselves into the neighbouring rocks. Thus the walls become more indurated, more crystalline, and for considerable distances are filled with the matters of the vein; and even the very substance of the rocks is impregnated with mineral combinations. In a Country where the veins are numerous, large masses of the rocks may in this way be *ridered*, as it is termed in the North of England; and if such a gradation of characters could be relied on as proof of contemporaneity of origin, this may in a few cases lead to the conclusion, that the veins and rocks are coeval.

But what is the true conclusion on this point? Is it not that these effects are locally related to the veins, because they are a consequence of their influence, or rather of the agency which occasioned them? That the ridering of the neighbouring rocks is coeval with the production of the vein may be allowed; but because these rocks are clearly defined from the veins, and fragments of them are enclosed in the veins, and the mineralizing influence which they have suffered obviously depends on the influence of the veins, we cannot hesitate to admit that these latter are of separate and subsequent origin. These facts are similar to what occur in other mining districts, where the stratification and consecutive depositions of the rocks divided by veins is perfectly evident, and where, therefore, contemporaneity of the veins is impossible.

In different rocks.

2. It is found, that when veins divide different sorts of killas or other rocks, that their contents vary in some inconstant manner, according to the nature of the rocks; and, therefore, it has been sometimes argued, that the production of the one is dependent on the other. The most usual notion on this subject is, that the veins may be viewed as secretions from the rocks; and by some this is supposed to have happened after the production of fissures; by others, by a mere internal separation of the parts of the mingled metallic and earthy mass.

This notion of the slow separation of the ingredients of rocks is in accordance with the principles and facts of Chemistry, and must be often appealed to, if we would explain by *true causes* the phenomena of mineral veins; but with respect to the question before us it is indecisive, and may with equal propriety be applied to veins of fissures and veins of segregation. The same electric attractions between certain minerals in veins, and certain rocks about them, obtain in the secondary strata, as in the slates and granites of Cornwall; but if the preexistence of fissures in the former is certain, why shall we deny it in the latter?

Contemporaneous veins.

3. There are combinations of minerals in masses of various figure, which, upon very good grounds, are admitted to be contemporaneous with the rocks in which they lie; and if we choose to call by the name of veins all such distinct combinations of minerals, these certainly are contemporaneous veins. When in granite, greenstone, &c., we find particular portions either linear, tabular, globular, or in any other figure which have a different proportion of ingredients from the other parts, and in consequence become conspicuous and distinct, except at the edges, which graduate without any sign of fissure into the ordinary mass of the rock; these may certainly be pronounced contemporaneous veins, and they have been produced by a process of secretion or segregation during the crystallization of the rock. These cases are perfectly distinct, and by contrast place in still more striking light the true relative age of veins of fissures.

In some instances veins of calcareous spar or other minerals lie *wholly included* in limestone masses, and these are properly called veins of segregation, but they are *not contemporaneous veins*, for they have clearly been fissures filled at some period since the consolidation of the rock, and the proof is, that shells, corals, &c., are split and sometimes displaced by these sparry veins, which undoubtedly occupy cracks left by the shrinking of the rock in the process of consolidation.

Upon the whole then, allowing every just latitude to the doctrine of contemporaneous veins, we must admit that the greater number of veins are posterior to the rocks which enclose them.

Intersection of veins.

This granted, we may return to the intersections of veins. The most simple case is when two straight veins cross without any change of direction, or any lateral displacement; and the order of effects appears to be the production of a fissure, and the filling of this by

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a vein, which was afterwards broken through by another fissure, and this, in its turn, received another mineral vein. It seems difficult to doubt the truth of this explanation; for if the vein which cuts through the other be subsequent to the fissure in which itself lies, it must also be subsequent to the vein which that fissure divides. The occasional complication of the problem by the number of intersections does not at all change its nature.

Appearances at the crossing.

There are, however, two things to be attended to, which require further consideration. It is sometimes observed, that the vein which upon this theory is the oldest, suffers a particular kind of accident at its junction with the other. It is divided into several branches on one or both sides of the cross veins, and these branches enclose portions of the neighbouring rocks. There is some difficulty in this case however it be considered, and we must demand more exact accounts than are usually met with of these facts before attempting to reason upon them. The coincidence of this splitting of a vein with the crossing of another vein, may often be only accidental; for such splitting frequently occurs in a wide vein, far from any cross course.

The fissures which have received the mineral veins are in most cases accompanied by slips or dislocations of the strata in a vertical direction, and the veins are of course subject to the same accidents of displacement. When two veins cross, and both are vertical, the lines of bearing of the two portions of the displaced vein must remain coincident after the fracture; if the divided vein be not vertical, its separated portions will have their lines of direction parallel, but not coincident; and in any horizontal plane they will *appear* to have sustained a lateral movement. Thus in the diagram, pl. vii. fig. 13, the cross vein *a* and the divided vein *b* are both vertical, but the divided vein *c* is inclined in the direction of the arrows, and its *apparent* lateral displacement is really due to a vertical movement. If two divided veins are inclined in opposite directions, and be dislocated by the same cross vein, they will appear to have moved laterally in opposite directions, as *c* and *d*.

Were we to include the cases of the inclined cross veins, and also those where the inclination of these veins varies both in amount and direction, the results would become too complicated for explanation without mathematical symbols; and we must, besides, remember that the displacement of the strata is really very seldom in a vertical direction, but generally accomplished by an angular movement from some fixed point, or round a virtual centre. We must, therefore, be very slow to admit the difficulty of the problem of the displacement of the solid masses of the earth as an argument against the received opinions, concerning mineral veins, for this principally depends on the want of precise and sufficient data.

Several remarkable cases which occur in the mines of Cornwall have been simply explained by Mr. Lonsdale, and there can be no doubt that the application of the principles of solid geometry to other complicated phenomena of that interesting region will gradually remove much of the mystery which has been supposed to hang over them.

Geographical relations of Veins.

Though, properly speaking, there is no real connection between mineral veins and the external physical configuration of the earth, yet, as this configuration is connected with peculiarities of internal structure, it is generally found, as Werner long ago indicated, that mining districts are almost entirely confined to the vicinity of mountains or elevated land, because in those situations the rocks were most dislocated by slips, and divided by fissures at the period of their elevation. It is not the absolute height of the ground, but the circumstance of its having been much exposed to subterranean convulsion that determines the prevalence of mineral veins. The rich mines of Cornwall are in comparatively low situations, but they are all in the vicinity of erupted and elevated rocks.

There appears to be no limit either of height above or depth below the sea, which defines the productiveness of veins, though in some Countries the higher, and in others the lower situations are most favourable.

It is sometimes found that the contents of a vein vary with the depth, without any particular geological conditions; as for instance in Cornwall copper is prevalent in the mines at greater depths than tin, and in the slate tract of Cumberland veins which bear lead near the surface yield copper in the deep. In other cases there appears a peculiar determination of the metallic ingredients to particular situations. The mines about Ecton yield copper; those of Derbyshire generally lead; in the Penine chain the veins generally yield lead, but toward the Eastern and Western limits of the district copper becomes less uncommon.

The length of a vein of fissure is perhaps hardly in any case certainly known; because when it ceases to be worth working, it is for all the ordinary purposes of mining said to be dying out, or cut out, or ended. The richest veins are productive for limited lengths, but the fissures which they fill may be, and are often extended far beyond the spaces occupied by metallic impregnations. Some of them are known to extend, and to be productive for many miles in the Harz, in Cornwall, and in the North of England. The width of veins is various, in different veins, but generally nearly constant in the same vein. A width of twenty feet is very unusual; most veins are less than six feet wide.

Directions of mineral veins.

There is a peculiar geographical relation of veins which is very difficult to understand, but which is so general that it may eventually be of the greatest value in correcting and perfecting our theories concerning them. This is the general *direction* of the veins. The most general direction of the great dykes and faults in the North of England, may perhaps be defined to be nearly East and West. But this is much more certainly true with respect to the mineral veins of the limestone districts of Weardale, Allendale, Alston Moor, and all the mining districts of Yorkshire; and it is equally recognised in the primary tracts of Cumberland, Westmoreland, and Lancashire. This is so general a fact, that the East and West veins are called right running veins, while the few which range more nearly North and South are called cross courses. These latter are seldom rich in metal; they often cut through and shift the right running veins laterally, as both of them shift the strata vertically. There is often to be observed a sort of compensation in the dislocating effects of veins. In Weardale most of the veins throw up to the North, while the parallel courses in Allendale and Alston Moor throw up to the South. The lead veins of Flintshire and Cardiganshire have the same East and West direction, and so have those of Mexico.

The lodes and veins of Cornwall are most generally

East and West veins, or nearly so; and these, according to Mr. Carne's (*Trans. of Geol. Society of Cornwall*) excellent Memoir, the *oldest veins* in that district, being traversed by the oblique veins and by the cross courses elvans and flukans. But not all the East and West lodes are of the same age, the tin being older than the copper; neither are all the East and West tin veins of one age, for those that underlie to the North, are generally traversed by them that underlie Southwards. These curious generalizations are not to be overthrown by particular discordances; their value may one day more fully appear, and they are certainly supported by analogous though less varied occurrences in other Countries.

The general order of their dates may be thus expressed.

Directions of veins of different antiquity.

1. Oldest, East and West, tin veins underlying to the North.
2. East and West, tin veins underlying to the South.
3. East and West, copper veins generally East 10° South.
4. Oblique or *contra* copper veins, generally East 30° to 45° South.
5. Cross courses not metalliferous, North and South.
6. Copper lodes of more recent date and lead veins.
7. Cross flukans or clay dykes nearly North and South.
8. Slides in all directions, but generally East and West.

The porphyritic and other dykes called elvan courses, are very generally divided by the veins, and seem to be of greater antiquity.

Werner has observed this geographical relation of mineral veins, and states the two following cases. In the mining district of Freyberg are two classes of veins very different from one another. One of these classes consists of veins which run from North to South; the veins of this contain lead glance, black blende, iron, copper, and arsenic pyrites, quartz, and brown spar. This is the oldest vein formation. The second class of veins which always traverse the former, and are never crossed by them, contains lead glance, radiated pyrites, heavy spar, fluor spar, and quartz; they stretch between the sixth and ninth hours of the mining compass (East to South-East.)

The mining district of Ehrenfriedesdorf, contains veins of tin and silver glance. The tin veins are always traversed by the silver, the direction of the first is between the sixth and ninth hour, (East and South-East,) that of the last from the ninth to the third hour. (South-East, South, South-West.)

Anothe geographical relation.

There is observed in some mining districts another remarkable relation of metalliferous veins to geographical lines. Though in the North of England the most frequent direction of the *veins* be East and West, the *mining districts* seem rather to be ranged in lines from North to South. The nature of this relation will be more easily understood if we add that both in Cornwall and in Cardiganshire, where the veins are also most frequently East and West, Mr. J. Taylor has observed lines of greater productiveness ranging nearly North and South, across the bearing of the veins. These curious notices suggest the inquiry whether the lines of productiveness are dependent on any principal axis of dislocation or on the occurrence of cross courses. The former case seems to be vaguely indicated by the phenomena in the North of England; perhaps the latter may be more applicable to Cornwall.

Connection of Fissures and main Joints.

The remarks on the joints of rocks in p. 543, 544, may be referred to as sufficient to show the importance of studying their direction in connection with that of the fissures of mineral veins. It is certain that in the limestone dales of the North of England, mineral veins are sometimes directed along the master joints of the rocks, also that in the slate tracts, veins and dislocations range along the cleavage planes of the slates. (Craven.) Dr. Boase has noticed the same thing in the slate tract in Cornwall, and such observations will doubtless be multiplied. Mechanical considerations might have led us to anticipate this result; for the main joints and cleavage planes would often be the lines of least resistance and yield more easily than other parts to any eruptive or depressing force applied to the planes of stratification. The direction of the master joints is certainly definite over large tracts of country, and if we should find eventually that mineral veins have commonly taken the same course, their regularity will no longer be an argument against, but an additional evidence for the vertical movement of the masses.

Relation of Mineral Veins to the Rocks which them enclose.

The relation of mineral veins to the rocks which enclose them offers a wide field of inquiry, which has been much studied, and yet is very little understood. It is difficult to distinguish clearly between the *accidental* and the *necessary* association of the phenomena of veins and rock masses; it is perhaps hardly possible at present to form a satisfactory opinion as to the amount of effects produced by causes acting from distant centres of force. We are in ignorance as to the subterranean operations of electrical and calorific agents still constantly going on; and to these theoretical difficulties must be added the unconquerable impediments to accurate and varied observation of the facts on which inferences are to be founded. Minute analogies of the relation of veins to the adjacent rocks would therefore at present be very unsatisfactory and hypothetical, and we must be content with the results which may be gathered from wide and general comparisons of phenomena on the grand scale. We shall confine the inquiry to metalliferous veins.

1. *Relation to the different kinds of Rocks.*

Considered as to their chemical nature, rocks may be classed as calcareous, argillaceous, silicious, and mixed; as to their mineralogical characters, as uniform, or varied, granular, compact, or crystallized; as to their origin, aqueous, igneous, or pyrohydrogenous. Metalliferous veins occur more or less frequently in every one of these classes of rocks. In limestone, in argillaceous slate and shale, in quartz and sandstone rocks, and in rocks of mingled ingredients; in uniform slates, and fragmentary millstone grit, in granular sandstone, compact limestone, and crystallized limestone and granite; in sedimentary grits and shales, in pyrogenous porphyries, basalts, and metamorphic conglomerates. The existence of mineral veins in a rock is therefore wholly independent of the particular chemical and mineralogical nature and proximate origin of that rock; nor, when due allowance is made for the relative prevalence of the different kinds

of rocks, does there appear any reason to admit that any preference or more frequent occurrence of metalliferous veins in rocks of particular kinds can be traced, *except in particular districts.*

Veins of certain metals.

There yet remains the inquiry whether certain metals are specially associated with or related to particular sorts of rocks. In order to answer this question satisfactorily, we must not content ourselves with instances such as tin veins and mercury veins, which occur in so few localities as to be rather dependent on their geographical position than on their geological repositories, but must cite veins of lead and copper, and disseminated ores of iron and manganese. Hardly any substance is more abundant in the mineral kingdom than iron pyrites: it occurs both in veins and disseminated crystals or concretions; and, in one or other of these states, it is associated with almost every known rock. It occurs disseminated in limestone of various kinds, as primary limestone, carboniferous limestone, and chalk; in clay slates, shales, and clays; in greenstone, amygdaloid, and basalt. Veins containing iron pyrites traverse rocks of as great diversity. Copper pyrites is not disseminated through so many rocks as iron pyrites, but it occurs in veins which traverse limestone, sandstone, and shale, clay slate, mica schist, granite, &c. Ores of manganese are also very generally diffused through rocks of very different kinds. The converse is true. In one and the same kind of rock occur veins of copper, lead, silver, and tin.

Affinities of metals to certain rocks.

There are some metalliferous veins which traverse different sorts of rocks, and give us an opportunity of ascertaining whether any differences in the contents of the veins correspond with the variations of the rocks. The tin veins of Cornwall sometimes pass through clay slate and granite; they produce ores in both. "A vein that has been productive of copper ore in the clay slate, passing into the granite, becomes richer, or, what is more remarkable, furnishes ores of the same metal differently mineralized. If we pursue it further into the granite, the produce of metal is frequently found to diminish. A change of ground is looked upon by miners as affording reason to expect an alteration for better or worse." Taylor, *Report on Veins.*

In Silesia.

Remarkable instances of this relation are given by Von Dechen (De la Beche, *German Trans.* 594.) The numerous veins which cross the steeply inclined strata of greywacke in the Liegen district, are metalliferous in narrow bands *parallel* to the inclined beds of greywacke. The veins of the Kupferberg, in Silesia, bear ore only in the hornblende schist, and are impoverished in mica schist. At Joachimsthal the mica schist is traversed by quartzose porphyry in veins, which, as well as the contiguous rock, hold pyrites. The rothegang of Elias consists in mica slate of loam, and holds only uranite; where it runs between mica schist, and a porphyry vein, and where it traverses the latter, its substance is a red hornstone, and it bears vitreous silver, native silver, arsenical-kobalt, bismuth glance, kupfernickel, arsenic, and bismuth; but red silver, elsewhere abundant, is entirely wanting.

In North of England

In the lead veins of the North of England, which are situated in the carboniferous limestone tract, a singular dependence is observed between the contents of the vein and the nature of the adjacent rock. The vein divides limestones, sandstones, and shales, and these are brought variously into opposition by the dislocations which accompany almost all the veins. The vein is sometimes productive of lead ore under every case of opposition on rocks. Where limestone, or schist, or solid sandstone forms the walls, its productiveness is at the maximum, but generally it is contracted in breadth and impoverished in its metallic contents, wherever it is included between walls of shale, and even where only one side is occupied by shale, the same effect is frequently observed. It would appear that the impoverishing influence of the shale is referrible to mechanical causes. In the same way as the shales in a coal-pit swell out from the undisturbed parts to fill the artificial vacuities, so we may conceive them to have done into the natural fissure; this will account for the contraction of the vein. In the process of crystallization, to which all the contents of a vein are subject, it seems conformable to analogy to suppose, that the permanent walls of limestone and gritstone would permit a more early growth of sparry and metallic crystals, than the crumbling edges of shale; a supposition, perhaps, confirmed by the occasional mixture of shale in the sparry mass of a vein, where it is "nipped," as the miners say, in beds of shale. There may be something in this due to electrical affinities, and we may perhaps apply the same supposition to the cases in Cornwall and Germany, quoted above, where the deposition of the ores is influenced by change of ground.

Quantity of lead ore from different beds of limestone.

From some or all of these causes it happens in the North of England that *certain* limestones are very much more productive than the others; in different mining districts, *different* limestones are thus favourably distinguished, but in the country of Alston Moor, Teesdale, and Swaldale, the uppermost thick limestone is by far the most rich in lead. To prove this, and at the same time to record a valuable fact, we may copy from Mr. J. Taylor's Report on Mineral Veins (*Reports of the British Association*, vol. ii.) the following statement of the quantities of lead ore actually extracted from the several sites of bearing beds in Alston Moor in the year 1822, according to the account of Mr. Dickenson; we have added the thickness of the several beds.

	Thickness in yards.			
Limestone beds :—				
Great limestone	21	20.827		Bings of 8 cwt. each.
Little limestone	2	287		
Four fathom limestone	8	91		
Scar limestone	10	90		
Fine bottom limestone	8	393		
			21.688	
Gritstone beds :—				
High slate sill	8	107		
Low slate sill	7	289		
Firestone	11	262		
Pattinson's sill	4	259		
High coal sill	4	327		
Low coal sill	3	154		
Tuft	3	306		
Quarry hazel	10	44		
Nattrass gill hazel	6	21		
Six fathom hazel	12	576		
Slaty hazel	4	18		
Hazel under scar limestone	4	2		
			2.365	
Whole produce of the mines of the manor, 1822.			24.053 bings.	

Upon the whole there is no sufficient evidence to show that the local *production* of metallic substances is in any special manner dependent upon the chemical or mineralogical composition, or the circumstances of the forma

tion of the adjacent rocks, though in some particular, and, indeed, many instances, we observe the *aggregation* of the substances in the vein to have been decidedly influenced by some peculiar conditions of the including rocks.

Walls of a Vein.

Alteration of substance.

The walls or cheeks which form the more or less definite boundaries of the vein present several facts worthy of notice. In some instances they are highly indurated, as if in contact with trap rocks, (North of England,) very often fissured, so as to break parallel to the vein, in others it seems as if certain sorts of rock (as clay slate, both in Cornwall and Germany) were greatly softened, and even converted to clay, along one or both sides of a vein. Werner mentions the decomposition of felspathic and hornblendic rocks for a fathom from the vein. We have also witnessed the fact of limestone, usually a blue or grey crinoidal rock, burnt, as the miners term it, that is converted to a brown granular crystalline rock. (Teesdale.) Another remarkable effect in the walls is the production of slickenside, so long known in the mines of Derbyshire, which are situated in limestone, and filled with fluoric and barytic shales and yield lead; in those of Cornwall, which are in killas, and with a matrix of quartz, and yield copper; in the magnesian limestone of Yorkshire, where copper or lead lines the limestone cheeks; and in the faults of the coal system of Yorkshire, where neither spar nor metallic matters occur. These and many other occurrences of rubbed surfaces along planes of fissures speak a plain language, and prove to the fullest conviction, the mechanical movement of the sides of the fissure upon one another, or upon the contained substances. The groovings of the surfaces, thus produced by rubbing, indicate, of course, the line of the movement; the circumstance that the polished faces are partially covered by lead ore, copper ore, &c., as the nature of the vein is, proves, moreover, that the movement was, in such cases, posterior to the introduction of the whole or a part of the mineral impregnation, so that the same fissure has been, in such cases, the plane of more than one convulsive movement. We may, perhaps, eventually draw from examinations of this phenomenon, in connection with and apart from mineral veins, some decisive results as to the time and other circumstances connected with the movements of the masses. How can the Geologists of Cornwall doubt the reality of those angular movements, which have left such clear evidence as the fine slickensides of some of their veins of fissures? We think with Von Dechen (*German Transl. of* De la Beche's *Manual*) that any other than the received explanation adopted above is impossible.

Slickenside.

2. *Relation to the different Ages of Rocks.*

This relation evident.

There can be no doubt of the fact that the local occurrence of metallic veins is in a very great degree dependent on the relative antiquity of the rocks in the district. It is in the primary, transition, and carboniferous strata, and in the igneous rocks associated with them, that all the veins in Great Britain are worked. In a few instances veins of small value, producing lead and copper, pass through the magnesian limestone, but not a single example is known of a true metallic vein in the oolitic, cretaceous, or tertiary strata, The connection of metallic veins with the older rocks is not an accidental coincidence, but a constantly recurring phenomenon, and the absence of such veins from the newer strata in England cannot be resolved into any circumstances of the geographical position of these strata; for both around the metalliferous slates of Cumberland and limestones of Derbyshire, the new red sandstone formation is extensively spread in contact, and yet not one lead or copper vein occurs in it. Any one who should confine his attention to the British Isles might infer that the causes of the production of mineral veins had been almost wholly inactive ever since the carboniferous epoch; and as a general expression, this may apply to the Continent of Europe, though both in the Pyrenees, and around the central granitic tract of France, metalliferous veins, apparently originating in these rocks, traverse strata of the oolitic and cretaceous systems.

The same relation obtains in rock dykes.

It must here be remarked, that both in Great Britain and throughout Europe rock veins and basaltic dykes are in the same manner abundant in the primary and rare in the secondary and tertiary strata. This is one of many general analogies tending to substantiate the opinion previously advanced upon more specific points of agreement, that rock veins and dykes, and metalliferous veins, form two parallel series of igneous products developed during the same geological periods, by the same general causes, acting under different circumstances upon different materials. From all our previous investigations, we have been led to the conclusion, that in the earlier geological periods, the chemical effects of heat and mechanical effects of heat were more conspicuously exerted; and if to this we join the consideration that all the disruptions by which igneous rocks were put in contact with secondary and tertiary strata, must have been experienced by the older strata, from beneath which the expansive force originated, we shall be able to perceive why the primary are so universally and the secondary and tertiary strata so partially enriched with mineral treasures and diversified by rock dykes.

Very modern veins.

As an example of veins of more recent date, we may quote Von Dechen's notice of the veins of Joachimsthal. In this case the dykes of basalt and wacke which divide the mica slate are themselves cut through by the mineral veins. These dykes are variously connected with great overlying masses of basalt which break into the brown coal formation. It is therefore evident that the silver, arsenic, and kobalt ores have been thrown into the veins at a later epoch than that of the brown coal tertiary deposit at the foot of the Bohemian Erzgebirge.

Werner appears to have been strongly impressed with the belief, conformable to his general theory, that vein formations might be classed as to their ages by mere examination of their component substances. When veins, even in distant Countries, contain the *same* ores and vein stones, and when these are arranged in the same determinate order, he concludes that they belong to one and the same general formation. Illogical and hazardous generalizations are frequent among practical men, and are too often introduced among the valuable facts recorded as a basis for Werner's Theory of Veins. A prudent reasoner would scarcely venture to trust an inference for *time* upon data which indicate only definite *chemical action*, even in a limited district, and it must be with some distrust that we can admit Werner's eight principal vein formations in the mining field of Freyberg; because he does not state *expressly* that his inferences concerning their relative antiquity were based on observations of their intersections.

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Werner's eight systems.

The following abstract of the account of these eight systems of veins will show the kind of description which should always be given of mineral veins.

The first and oldest produces abundance of argentiferous lead glance. It consists of coarse granular lead glance with from one and a half to two and a half ounces of silver per quintal; common arsenical pyrites; black blende in large grains; common iron and hepatic pyrites; sometimes a little copper pyrites, and a little sparry ironstone. The veinstones are chiefly quartz; sometimes a little brown spar; rarely a little calc spar. These substances occur most generally in veins ranging from *North to South*.

The second yields lead very rich in silver. It contains lead glance large and small granular; black blende in small grains; iron and hepatic pyrites, and a little arsenical pyrites. In addition, dark red silver ore, brittle silver ore, white silver glance, plumose antimony ore. The veinstones chiefly quartz, with much brown spar and often calc spar. The veins range *South and South-West*.

The third yields lead glance with one ounce of silver per quintal, much iron pyrites, a little black blende, and red iron ochre. Veinstones quartz, sometimes with chlorite mixed and surrounded with clay. Veins range *North and South*.

The fourth yields lead glance with one-fourth to three-fourths of an ounce of silver per quintal, radiated pyrites, and sometimes brown blende. Veinstones heavy spar, fluor spar, a little quartz, and rarely calc spar. Veins range *East and West*. (To this system Werner boldly refers the veins of Derbyshire, the Harz, and also those of Gisloff in Scania!)

The fifth consist of native silver, silver glance, and glance cobalt, sometimes with grey copper ore, lead glance rich in silver, fine grained brown blende, and sparry ironstone. Veinstones, heavy spar in a state of disintegration, and fluor spar. It always occurs in the *intersections* of the first and fourth systems. (North and South, and East and West.) It sometimes is found even in the middle of the Westerly veins.

The sixth contains native arsenic and light red silver ore; with a little orpiment, copper nickel, glance cobalt, native silver, lead glance, iron pyrites, and sparry ironstone. The veinstones are heavy spar, green fluor spar, calc spar, and a little brown spar. Occurs in the intersections of the fourth and fifth systems, or in the middle of veins.

The seventh is of red ironstone, with a little iron glance, quartz, and heavy spar. Occurs in the *upper parts* of veins.

The eighth and newest is of copper pyrites, mountain green, malachite, and red and brown iron ochre, with a little quartz and fluor spar.

3. *Relation to the Local Centres of Igneous Action.*

Our investigations lead directly to the inquiry, how far the geographical occurrence of metalliferous veins is connected, as that of rock dykes is known to be, with the eruption of igneous rocks and the movements of fluid masses within the Globe?

Satisfactory evidence on this subject can be obtained in two ways: 1. By comparing metalliferous and nonmetalliferous districts of old strata in their geographical relation to igneous rocks and convulsions. 2. By comparing the relation to igneous agency of the locally metalliferous newer strata.

Geology. Ch. III.

In older rocks.

The older rocks are not by any means universally stored with metalliferous veins any more than with rock dykes. Very large tracts in the slate rocks of Devonshire are nearly devoid of metals, but near the granitic masses of Cornwall they are abundantly supplied with veins. In the vast districts of Wales the slate rocks yield copper and lead chiefly along the Western borders of the Principality, where the local centres and axes of elevation are situated. Amid the Cumbrian Lakes, lead and copper veins adjoin the granitic, hypersthenic, and syenitic axis of Carrock, Skiddaw, High Pike, &c. They occur near the porphyries and traps of Helvellyn and Old Man, but the greater portion of the slates, far removed from the foci of disturbance, are devoid of mineral treasures.

In Scotland, metallic veins adjoin the granitic nucleus of Strontian.

The mining tracts of the Harz, the Erzgebirge, Hungary, Brittany, and other localities are convulsed by disruption and diversified by the intrusion of granitic and porphyritic rocks; the Ardennes mountains, which yield few veins, develope hardly any igneous rocks.

The carboniferous limestone tracts of Mendip, Derbyshire, and Flintshire, of Wharfdale, Swaledale, and Aldstone Moor, have been shaken to pieces by many convulsions, and they are very rich in lead, zinc, and calamine; but the greater part of the Yorkshire and Northumberland limestones, affected by only one or a few general elevations, are poor in metal.

In newer rocks.

The newer rocks are metalliferous only in the vicinity of the foci of their disturbance, as round the central granite of France, near the igneous masses of the Pyrenees and the Alps; in all which places, the metallic ores are so related to the igneous rocks that they occur only in a narrow zone at the junction of the igneous and the altered stratified rocks. (Observations of Dufrenoy, Von Buch, &c.)

Conclusions on this subject.

As both these methods of comparison lead to one result we may venture to adopt it; and the more readily because, in preceding sections, we have found the geographical situation of mines to be related to the elevation of the ground, and the metalliferous strata often identical with those in which rock veins abound. Nevertheless we must not shut our eyes to some decided differences between the situations of dykes and veins. For instance, the Island of Arran is traversed by hundreds of dykes of basalt, porphyry, and pitchstone, but metallic veins are almost unknown there; Aldstone Moor is dissected like a map by veins of lead ore, but very few whin dykes occur there; on the contrary, in Northumberland and Durham whin dykes abound in the coal tracts where lead is hardly known. It is, besides, too remarkable a thing to be overlooked, that South of the Yorkshire Swale hardly a whin dyke or porphyry dyke is known through the metalliferous tracts of Derbyshire, Somersetshire, and Flintshire. This contrast is the more remarkable in the country about the sources of the Tyne and Tees, because there basalt has been erupted in vast quantity, and at its Eastern termination appears related to several dykes of great extent. This mass of basalt is traversed by the veins in the same manner as the limestone is, and we may, perhaps, hazard the speculation that under this tract of country lay at one time melted basalt, and at a subsequent time the metallic and mineral combinations which fill the veins. Will it be thought too great a stretch of fancy to attribute this change of the igneous materials erupted in the same

tract of country to movements in the internal nucleus of the Globe not isochronous with the rotatory velocity of the solid superficial crust?

Electricity of Veins.

The direction of electrical currents at small depths below the surface of the Earth, is a subject on which theory is at present silent, and which has only recently been proposed for observation. The observations of Mr. Fox in the mines of Cornwall and Devon and North Wales, are still the most important of the kind. Mr. Henwood is engaged in further inquiries. As far as appears at present, the interest attached to the solution of this question belongs more particularly to Electrical Science, and, perhaps, both chemical and thermal disturbances of equilibrium may be concerned in the effect. These currents may be due to local causes. Mr. Taylor very properly observes, (*Reports of the British Association*, vol. ii. p. 18.) that by the very act by which we gain access to a vein we lay it open to atmospheric action, and consequently to decomposition.

Mr. Fox's experiments.

Chemical agency commences, and with it, very naturally, galvanic influences are excited. Veins containing ores little subject to decomposition have, he apprehends, been found to give little or no indication of this nature.

Mr. Fox appears to think that the direction and intensity of the currents which pass along the veins may be so related to the position and quantity of metallic matter, as to give reason to hope for some direct useful application of the results to the Art of Mining. But the novelty of Mr. Fox's experiments, and the connection of the currents with mineral veins, led some Geologists to adopt the very hasty conclusion, that the production of the veins was mainly owing to such currents. It is very probable that electrical currents have really been concerned in the distribution of metallic ores both in veins and rocks, for when is this agency absent from any great chemical phenomena? But to conclude, without any intermediate steps, because mineral veins are channels for electricity, that they have been produced by electricity, is the same thing as to ascribe to electrical currents the construction of the galvanic battery.

CHAPTER IV.

GENERAL INVESTIGATIONS AND INFERENCES.

Section 1.

On the Consolidation and Alteration of Stratified Rocks.

In a preceding section we have seen the effects produced by the Plutonic rocks upon the strata which they penetrate; effects which suggest to our minds so vivid an impression of the action of heat, that even in the absence of all other arguments from facts, we could not refuse to allow that those rocks had been local centres of heat. The independent evidence arising from the composition of the rocks satisfactorily confirms this inference, and permits us to apply it in circumstances when the actual proximity of igneous rocks cannot be ascertained. These effects seem to be reducible to several cases, depending on the degree of heat communicated, and the substances operated on.

Effects of Plutonic on stratified rocks.

1. The *consolidation* of stratified rocks is exemplified in the induration and contraction of shale, and in the developement of new faces or joints in it, which sometimes meet one another rhomboidally, and sometimes follow the columnar relations of the adjoining basalt.

2. The *partial fusion* of some part of the substance of a rock, so as to conglutinate its grains, and solidify and harden the whole mass. Thus sandstone is converted to a granular quartz rock.

3. The complete fusion or vitrification of the rock; thus converting shale into Lydian stone and sandstone into a kind of jasper.

4. The complete fusion and consequent rearrangement of the particles into granular or crystalline forms, as in the instance of common chalk in Ireland, common limestone in Yorkshire, the Isle of Sky, and Carrara.

5. The generation of minerals not before existing in a distinct state in the substances affected. The production of pyrites, asbestus, anthracite, plumbago, garnet, &c. along the contact of igneous and aqueous rocks, is a very characteristic and general effect which appears to result from the actual transfer of the metallic and other matter through the solid substance of the rock, in virtue of electric attractions which may be considered as imparted by the heat.

If Von Buch's notion of the impregnation of rocks with magnesia in the vicinity of augitic trap rocks should eventually be substantiated, it must be considered as a remarkable example of this electric transfer.

6. The sublimation of some portion of the neighbouring substances. Thus the charring of coal, the desulphuration and the debitumenization of shale, are very directly connected with the heating power of the igneous rock, but it is probable that some peculiar conditions were required for such effects in the submarine depths, where most of these operations were performed.

The almost universal coincidence of convulsive dislocation of the strata with eruptions of plutonic rocks, seems enough to prove their common dependence upon one pervading cause of internal movement. In the same manner as the modern earthquake precedes the eruption of lava, so the ancient convulsion preceded the injection of plutonic rocks. Also precisely as in the present day the earthquake shakes Countries far removed from volcanic centres, so in more ancient periods many tracts were convulsed but not filled, at least near the surface, with melted rocks. As far as at first appears, the common dependence of the two orders of effects upon one cause, is merely to the amount that the mechanical transference of melted rocks has been effected by the same internal pressure which dislocated the strata; whatever occasioned the pressure, and whatever was the cause of the fluidity of the rocks.

Relation of igneous rocks to convulsions.

Various mechanical modes may be conceived, by which

such pressure may have been occasioned, and various conditions assumed for the production of melted rocks, and these may be wholly distinct from one another; but the *exhibition* of these rocks along the lines of convulsion can only be ascribed to the same mechanical cause which produced the convulsion.

The chemical theory of volcanos, advocated in the preceding pages, assigns a single cause for the chemical phenomena, and for the disturbance of the external crust of the Earth; and the same simplicity is sought for in one modification of the theory of an internal heated nucleus; but it may possibly be more correct to assign separate causes for the production of these effects. Judging merely from their relative frequency and geographical extent, we might be led to assign much more extensive agencies to the production of convulsions than to the elevation of igneous rocks. The whole area of the dry land has been subject not only to general elevation but to partial convulsions, several times repeated under the same spots; but igneous rocks are less universally, though certainly very extensively diffused. This distinction, however, loses much of its force when we consider, first, that plutonic rocks become constantly more and more abundant in comparison to the number of convulsions as we descend towards the base of all the strata; secondly, that though the effects of convulsion might pass through all the strata to the surface, and thus relieve the inequality of pressure, the melted matter from below could seldom penetrate the narrow and confused and cold passages left among the fractured strata, to any great elevation; thirdly, that rocks of igneous origin do really underlie the whole series of strata.

General basis of argument.

Upon the whole we may safely admit, that igneous rocks have been in a state of fusion beneath the strata, either simultaneously or successively, in all or nearly all parts of the Globe, and that the elevation of these has been always accompanied by convulsions. Instructed by the discovery of the effects of these rocks upon adjoining substances, we may now proceed to inquire into certain phenomena, of much more extensive occurrence, but of nearly a similar character, and which appear due to the pervading action of heat upon stratified rocks since their deposition.

Ratio of the consolidation of strata.

On reviewing the series of strata in relation to the degree of their consolidation, it is impossible not to perceive that this increases continually with the age of the rock; so that, taken as a group, the primary systems of gneiss and clay slate, with all their modifications, are far more consolidated than the other strata, while the tertiary strata are the least indurated of all. The same result is obtained by more minute comparisons of analogous rocks, the slates, shales, and limestones of the primary series, with the shales, and clays, and limestones, and marls of the secondary and tertiary strata. A plausible cause for this seems to offer itself in the greater pressure to which, it may be imagined, the lower strata have been subjected; but this is not sufficient to account for the whole effect of consolidation, and is directly negatived by the numerous joints and fissures, which indicate lateral rather than vertical contraction of the strata. The lowest strata are, besides, not merely in a high state of consolidation; some of them, as primary limestone, display in a most decided manner that crystalline structure which results from heat; others, as clay slate, are fissured in such a way as is known to have been locally occasioned by the heat communicated from igneous rocks; others, as quartz rock, show clear proof of having undergone, if not actual fusion, at least such an agglutination of the grains as can be produced by art in a furnace. The conclusion from all this is of great importance; for as these rocks are of almost universal occurrence below all the other strata, and their characters are not referable to the local proximity of igneous rocks, we are assured, taking into account the subjacent granitic rocks, of the almost universally pervading influence of subterranean heat.

Alterations of primary strata.

It is impossible at present to point out exactly the amount of changes which have been produced on the primary strata by the general and continued communication of heat from below; because, with respect to some of them, it is difficult to feel very confident of the precise state in which they were deposited by water. With respect to gneiss, for example, which is in some cases almost identical with granite, in other cases approximates to sandstone, it is hard to say how much of its granitoid character is due to subsequent metamorphism; because we have no certain means of knowing the degree of movement to which its ingredients had been exposed in water. Yet when we consider the bedded and laminated character of this rock, and observe that its constitutent minerals are mostly in a fragmentary state, and even when united into a dense rock, are not crystallized with regular external forms, we seem to understand that the rock has been solidified by a species of imperfect fusion at the edges of the constituent substances, which, carried to extreme, would have reconverted the whole to granite.

Similar remarks apply to mica schist, which, on the one hand, varies to gneiss, and on the other to clay slate; and it is observable that the fusible mineral garnet, which is known to have been generated at moderate heats in contact with trap, is very generally intermixed with the laminæ of gneiss and mica slate. (p. 562.)

Of clay slate.

Among clay slates of every degree of fineness of grain, the action of heat is chiefly evinced by the extreme condensation of the argillaceous substance; by the regularity of the system of fissures; by the interspersion of crystallized pyrites, hornblende, &c.; by the frequency of segregated quartz veins. Perhaps these latter occurrences may be due to local causes; but the systematic fissures and cleavage of slate is a general fact, which is most striking in the deeper parts of the deposit, and gradually vanishes upward. So long as the basis of the rock is very fine grained, the cleavage structure will pervade it, and even cross laminæ of very course matter; but when the basis is altogether coarse, as in greywacke slate, the cleavage vanishes, and is only indicated by numerous fissures, dividing the rock into rhomboidal masses. In a given tract of country the planes of cleavage have one prevalent direction, and the system of fissures appears also definable in direction. The general horizontal direction of the cleavage planes in a part of the Cumbrian mountains is West North-West, which is exactly that of the great Craven fault. (*Geol. Trans.* New Series, vol. iii.)

It is usual and probably correct to consider the systematic fissures and cleavage of slate as a kind of crystalline structure on the largest scale; the angles of intersection seem, however, to be assignable only for very small distances, and they vary in different strata of slate. Something like polarity must perhaps be supposed to account for the constancy of the direction of cleavage.

It does not appear that the heat imparted to the primary strata has been always sufficient to destroy the

organization of shells or even plants, for shells occur in the slates of Tintagel and in Snowdon, and lie between gneiss beds in the Fichtelgebirge and Erzgebirge, and are noticed by Von Buch in the dolomite near Lugano. A long continued and pervading rather than a very high heat seems best to account for the phenomena. In the neighbourhood of igneous rocks, indeed, the local changes are of rather a different description.

If we rise to the contemplation of the carboniferous system we shall be able to trace in the generally high state of induration of the sandstones, shales, and limestones, and in the frequency, systematic direction, and continuity of the joints, clear evidence of the action of heat. But yet we perceive that these effects of heat are not nearly to the same degree as those in the primary strata. A simple proof of this is afforded by the limestone of Teesdale which is a hard rock, but which, where it touches the basalt of that country, has been subjected to nearly the same change as that observed in primary limestone: it has become crystalline. The shales are also altered. The upper portions of the slate system in Shropshire and Radnorshire, where that system is immensely thick, show the same changes.

Decreasing effects of heat in newer strata.

The effects of general heat continually decrease among the superior strata of the saliferous, oolitic, and cretaceous systems, and seem almost wholly lost in the tertiary strata. It is chiefly to this graduated effect of heat that we may ascribe the distinctness of the rocks in different parts of the series. Thus to take the calcareous rocks, we have a gradually changing series proportioned to their antiquity, from crystalline primary limestone, through highly condensed carboniferous limestone, to compact lias, concretionary oolite, marly chalk, and lacustrine marls; among sedimentary deposits there is a series from gneiss through the hard sandstones associated with the carboniferous limestone to the sands of the oolites, chalk, and tertiaries; and another from cleavable slate, through jointed greywacke slate, hard coal shale, compact red marl, and clay of the oolite, chalk, and tertiaries. There is properly no sand, clay, or marl among the older strata; indurated shale, hard gritstone, and solid limestone are of rare occurrence among the younger.

It does not appear that the occurrence of ironstone, pyrites, gypsum, &c. in detached masses among the stratified rocks is to be considered as in any direct or exclusive manner due to the influence of heat, but rather to the ordinary forces of molecular electric attraction operating during or after the deposition of the mingled mass of matter. The spar veins in septaria have undoubtedly been filled since the concretion of the clay balls, and for the transfer of the calcareous or silicious matter we must appeal to the same processes which have filled the cavities of shells and many cracks in limestone rocks with the same materials. No doubt in these effects an elevation of temperature might modify and perhaps accelerate the results, but it would be ridiculous, at present, to adopt Dr. Hutton's notions on some of these subjects.

Effects of heat on the deposition of strata.

The preceding examples show clearly the effect produced on strata by the action of heat since their deposition; there can be no doubt that the same powerful agency must, especially in the earlier eras of Geology, have greatly influenced the manner and circumstances of their deposition. On this subject, however, we have not at present much to record, and that little is wholly confined to the primary series of strata. There is one leading fact often connected with the stratification of gneiss, mica schist, &c. and not seldom repeated in chlorite schist and clay slate, which seems wholly unexplained by the direct action of heat upon these strata. The *contortions* of the laminæ of these rocks are very remarkable, and seem evidently coeval with their first formation, though in some instances Dr. Macculloch thinks they are most numerous where quartz veins penetrate the rock. These contortions may, perhaps, be understood by comparing them with some analogous cases in laminated sandstone, where the undulations and confusion of the laminæ indicate agitation in the water. If we allow that the water in which gneiss and mica schist were formed, was heated to a great degree by contact with or proximity to the sources of subterranean heat, the agitations of the ebullient liquid might, possibly, give to the strata then forming under it the very peculiar character of minute and irregular undulations which so often belong to these ancient rocks.

Deposition of limestone.

Another thing apparently characteristic of the mode of deposition of the primary strata is the isolated condition of the limestones which interlaminate the schistose rocks. How different in this respect are the detached often lenticular primary limestones of Scotland, and even the transition limestone of Devonshire and Wales, from the regularly continuous calcareous beds of lias, oolite, and chalk! Is it not very probable, that some local efflux of gases or the influence of local centres of heating agency, have sometimes performed the same effects as coral animals, and determined to particular points the extremely limited decomposition of the ocean water which undoubtedly was the source of the limestone deposit?

Section 2.

On Disturbances of the Strata.

The introductory observations in p. 540 to 543 may serve as a foundation for the following inquiries into the effects and causes of subterranean convulsion; and the remarks in p. 571, 597, 619, 634, 657, 688 may be read in connection with the preceding section of chap. iv. and the whole of chap. iii. This great subject may be carefully considered in four divisions.

1. The geological periods of convulsion.
2. The direction of convulsive movements.
3. The effects of convulsions in altering the relations of land and water.
4. Effects on the deposition of strata and on organic life.

Geological Periods of Convulsion.

Proofs of convulsion.

In order that our statement of results on this important subject may be as much as possible free from objection, it will be convenient to begin by fixing what phenomena are to be taken as proof of the occurrence of convulsions, and what method is to be followed in assigning their place in the scale of geological epochs. When strata, originally level, or nearly so, have been raised to high angles of inclination; when beds, originally continuous, are found to be broken asunder, and their separated portions placed in new relations of position, one portion being raised or depressed, or both deranged; when layers, originally plane, are found to be bent into extraordinary curvatures; in all these cases the conclusion is imme-

diate, that convulsions have happened in the very points where such phenomena occur. The only question which can arise, supposing the actual position of the rocks well ascertained, respects the certainty of our postulate of their *former* position. Persons who have read old books, but have not studied natural phenomena in this point of view, may be apt to suppose that, under particular circumstances, strata may be formed at high angles of original inclination. Those who have looked more narrowly into the matter, and have been instructed by Mr. Yates's observations on the positions assumed by earthy materials falling in air and in water, may be led to extend the judiciously limited inferences of this author to cases where they will not apply. For very limited areas, and in extremely troubled waters, the mountain torrents, or the surf of the ocean, tumultuous deposits of sand and pebbles happen, in which the laminæ may be inclined at considerable angles, and cover one another confusedly. On this account it seems not unnecessary to reexamine the basis of our argument, and see whether it will bear the weighty superstructure we design to lay upon it.

Examination of the basis of the argument.

1. General experience assures us of the general fact, that it is a characteristic effect of agitated water to deposit what sediment falls slowly from it in the form of strata whose upper surfaces continually tend to become horizontal. This is seen in inundations from a river, in shallow and ruffled lakes, and within the low-water margin of the sea. The form of the bottom influences the horizontality of the upper surfaces of the deposits in such a way, that where the bottom is like a pit, the stratified masses above are hollow on the faces; but these effects of the original inequality are rapidly obliterated by successive coats of sediment, all becoming more and more nearly horizontal.

2. In perfectly tranquil water, through which any fine sediment is equally diffused, the depth to which this will cover any part of the bed depends on the depth of the supernatant water, and on the *angle of rest in water* of that kind of sediment. The *angle* of rest *in air* for earthy substances is about 45°.

3. If a river bring sediment into agitated water, this will deposit it in strata tending to become horizontal, but with a constant dependence upon the point where the river enters, such that, the quantity of sediment being there always accumulating, a general conical slope therefrom in all directions will modify the horizontality of the strata.

4. If a river bring sediment into calm water, or into water suddenly deepening, so that all its lower parts may be considered as calm, the conical slopes from the point where the river enters will be much more abrupt than in the former case, in a certain proportion to the calmness and depth of the water. This Mr. Yates finds to be the case in the deep lakes which receive the abundant sediment of the boisterous torrents of the Alps; and, in consequence, we are furnished with a key which will ultimately open many curious results in the arrangement of sedimentary deposits. (See p. 707.)

On considering these cases with reference to stratified rocks, it is evident that instances coming within the class of conical deposits radiating round a point can only be of very limited occurrence, not likely to affect a general argument, and are, in fact, almost unknown. The estuary deposit of the Weald of Sussex shows no such structure; it cannot be traced in the Yorkshire estuary coal field; nor is there any mention of it in any lacustrine deposit which has been desiccated and exposed to our observation. It is very doubtful whether it can be recognised in any marine formation, and certainly it does not clearly apply to any class of marine deposits now in progress: at the same time we must admit that, in all cases, the action of the sea growing less and less sensible far from shore where the water deepens, the sediment brought by rivers and floods must be formed in attenuated masses, thickest towards the shores. This effect will be evident in exact proportion to the *falling velocity* of the particles in water, so that pebble beaches may lie in steeper slopes, and cover shorter breadths than sands, while fine clays will spread further into deeper water. (See p 709.) But all these slopes *in water* are very gradual, so that even against the rocky Eastern coasts of England, the deep waters have been filled up by sediments, which now assume a gently declining surface under the water, and a moderate slope above it.

Direct proofs of local convulsions.

For all the purposes of our present course of argument we shall therefore assume the law of original horizontality, or very moderate declination of the planes of *widely extended strata*, as amply supported by every needful proof from careful and scrupulous observation. Hence from adequate observations of the position of strata we can tell whether they have been altered in position or not by convulsions operating in those situations precisely.

Indications of convulsions.

Another class of appearances indirectly marks the effect of convulsion, either on the spot or at some distant point. When we find traces of a sudden and complete change in the whole course of the aqueous deposits, so that the quiet deposition of argillaceous or calcareous strata is interrupted and preceded by a tumultuous aggregation of pebbles, we know that there has been some access of agitation to the water. This may, according to circumstances, have happened from a periodical or accidental change in the drainage of the neighbouring land, or from some extensive change of the relations of land and sea. The latter cause may be reasonably adopted, provided that we find these indications of agitation very extensive, and provided that in some instances there be proof of the formation of local conglomerates following upon local convulsions. The latter requirement is found to be satisfied in many instances, and of the former it is easy to judge. One more indication of some distant convulsion affecting the relations of land and sea seems to be afforded from the rare case of the occurrence of one bed of marine shells among a vast abundance of fresh-water estuary deposits, (see p. 591.) without any local unconformity of stratification.

Such are the phenomena to be taken as proofs of convulsion: the most important are those which distinctly establish the precise localities of the disturbance. Let us now examine into the mode of argument by which the geological epochs of these disturbances are to be established.

How to determine the epochs of convulsion.

In all investigations concerning the period when an event happened, we may consider the result completely obtained. when the limits of maximum and minimum antiquity are known as precisely as the data allow. In geological inquiries, the answer is always expressed in terms of the scale of relative antiquity of the stratified rocks, and a convulsion is fixed in geological time, when it can be shown to have happened after the deposition of one stratum, and before the deposition of another. If the strata which thus limit the period of the convulsion be consecutive terms of the series of

deposits, the most precise attainable result is obtained; but if these limiting strata be not consecutive, the age of the dislocation is known only within a given range. An example of accurate determination of the geological era of a convulsion is afforded in the North of England, where the newest of the coal strata are found to be dislocated under the oldest red sandstones of the saliferous system. Instances of less precise determinations are common enough: for example, in the Mendip hills the dislocated mountain limestone is covered by undisturbed oolite, and, as far as this observation goes, the convulsion may have happened during any part of the long period occupied in producing the coal, red marl, and lias strata. In this case, however, by tracing the line of the dislocation to other localities, other strata are found to be so related to the limestone, as to fix the geological date of its disturbance within narrower limits.

If the dislocated strata be not actually seen covered by others which are undisturbed, another set of data must be employed. It may happen that around the disturbed rocks some newer stratum spreads in such a manner as to give sufficient reason to conclude that it was deposited since the period of the convulsion. This is, in most parts, all that can be observed with respect to the red marl around Charnwood forest, and it would be satisfactory evidence that the slaty rocks of that district were upraised before the period of the new red sandstone; and, in fact, we have found instances where the red marl does really cover with level beds the broken edges of slate.

If no horizontal or undisturbed strata be visible in any part of the dislocated tract, either in superposition or in juxtaposition, the limit of least antiquity vanishes, and we are in danger of imagining too modern a date for the convulsion; if the newer members of the dislocated group of strata be concealed, there is danger of ascribing too high an antiquity to the convulsion. It will be prudent to exclude all such cases from the argument: the others seem to be unobjectionable.

Question as to the duration of the convulsions.

There is yet another point of view of much importance to the following investigations. What we have termed the limit of greatest antiquity marks clearly the completion of the convulsion; but the progress of geological inferences has brought us to the point of requiring information whether the disturbances were very rapidly effected by one or a few sudden and violent efforts, or operated slowly by small and graduated movements. According to the former view, the whole amount of the dislocation was effected in so short a time that this may be regarded as nothing compared to the long periods occupied in the deposition of the strata; according to the latter, the disturbing agency might be at work during the whole, or some long part of the period of the formation of the dislocated strata, but ceased when their formation was complete. This is not a mere subtilty or needless refinement, it is very important to know which is the true doctrine: we believe it can be ascertained, for all instances where the facts can be clearly known; and though it would be premature to make any exclusive assertion, the general process of Nature may be satisfactorily inferred.

Faults.

Proceeding from the clearest indications on this subject towards those which are less easily interpreted, we may remark in the first place that those dislocations commonly known by the name of "faults" in the strata, (p. 541.) which break the continuity of the beds along a certain plane or fissure, and elevate or depress one side, plainly declare themselves to be the result of single convulsive movements. To be satisfied of this, it is quite enough to contemplate a diagram of the effects, pl. i. fig. 5, 7; but actual inspection of the phenomena will leave no room for doubt that the whole mass of dislocated strata was put into its present relations, not by a repetition of small and gradual movements, but by sudden and violent agency. A repetition of small movements through the whole vast thickness of strata could not fail to break down those clearly defined walls of the fissure which so generally exist, especially among the harder rocks, and leave the fissure filled up with a confused aggregation of all the substances on its sides, instead of a clear space for the subsequent admission of sparry and metallic matter, or regular traces of the movement of these faces on each other.

The extent of dislocation to which the name of fault accurately applies is extremely various, the difference of level thus occasioned being sometimes a few inches, in many 100 feet, in others as much as 200 yards. This makes no difference in the argument, but it serves to mark out in very clear characters the degree of force exerted in each case. It is remarkable that those dislocations which make the greatest difference of level, range through the greatest lengths of country; so that the ninety-fathom dyke, so named from the observed extent of its dislocation, ranges from the Eastern Sea across the whole breadth of Northumberland, and certain dislocations in Yorkshire have ranges of ten, twenty, and thirty miles in one straight line.

Great dislocations.

As far as we know, the greater portion of the convulsive movements, whose production we are now investigating, were accomplished by means of "faults." There are some very extensive dislocations which usually receive, and may perhaps deserve the same epithet, but which, for the purposes of our present argument, wear a somewhat different aspect. One of the most magnificent examples of dislocation in Europe is that grand break nearly along the line of the Western border of Durham and Yorkshire, from near Brampton by Brough and Kirkby Stephen to near Kirkby Lonsdale, the effect of which is to throw down to the West, relatively, the strata of the carboniferous system more than 1000 yards through a length of 70 miles. An axis of slate rocks rises along the line of fracture, which is also partially marked by dykes of greenstone. On the West the beds dip at high angles to the West; on the East they decline gently to the East. No proper plane of fault is traceable in this case of enormous disruption, owing to the circumstances of the country, and we must have recourse to other considerations to arrive at satisfactory inferences concerning the time employed in producing it.

In the first place we may remark, that this line of disturbance is cut off to the North by the ninety-fathom dyke, and to the South by the Craven fault; and there is every probability that it is actually continued along the lines of these faults to a direction right angled, or nearly so, to its own course. If this be so, and the whole is one complex dislocation, we may surely conclude that the middle portion, even if not of the same age as the extremes, was produced in the same manner.

Relation of faults to axes of convulsion.

Again, the numerous faults of an ordinary character which cross the country in all directions between these great lines of convulsion, seem evidently related to and dependent upon them; a remark which receives corroboration from many other parallel inquiries. Amongst

these faults it is possible, perhaps, to distinguish two periods of disturbance, the older one marked by a direction nearly East and West, which is that of most of the metalliferous veins, the other by a direction from North to South, which is that of several whin dykes, and some few lead veins. Perhaps these different directions may have taken their rise from the two directions of the axes of convulsion which bound the district.

The connection, however, is sufficiently clear to warrant our applying to those great axes of disturbance the limits of time by which the lesser faults are defined; that is to say, in many instances nearly coincident to the limits of uppermost coal measures and variegated new red sandstone.

Inferences.

It is apparent, therefore, that the evidence which can be collected on the subject of the simple dislocation of the planes of the strata, points to violent internal movement, occupying short periods of time for the accomplishment of the phenomena. There seems to be no mark whatever of gradual or many times repeated efforts.

Some cases of disturbance, however, are of a complicated nature, and may probably be found upon further examination to require the admission of many repetitions of violent movements and pressures on the same region. Such are the extraordinary retroflexures of the calcareous strata adjoining the Alps, the retroverted dips in the coal fields of Somersetshire and Belgium, and the flanks of the Malvern hills. It is not, however, easy upon any suppositions to meet the exigencies of these difficult cases.

What are usually called anticlinal axes of elevation, must, likewise, be considered as yielding insufficient evidence concerning the length of time elapsed from the beginning to the end of the disturbance. In some cases, indeed, the dips on either side from the axis are so steep that they seem to refer themselves to single and violent movements, but where, as in the Weald of Sussex, the appearances along the axis indicate that there the disturbance has been moderate, while toward the sides it has been extreme, the breadth of the country being considerable, there seems on a first view no very good reason for coming to a decision at all, as to the prolonged or transitory nature of the convulsing agency.

There is, however, an indication worth pointing out for the future guidance of observers on this branch of the inquiry. If we imagine that during the deposition of any class of strata, an anticlinal axis is formed so that they are gradually uplifted and converted to dry land, we may be sure that all the strata would be found to grow continually thinner from either side toward the axis of elevation, at which line they would become evanescent. Very few instances can be quoted where many strata are actually seen to be continuous over the anticlinal line. The Isle of Wight, the elevation valley of Woorlhope, (*Geol. Abstracts,*) the Hampshire and Wiltshire chalk, and some remarkable cases in Swisserland, seem to be, however, sufficiently in point, and no traces of such a diminution are there observable.

General conclusion.

Upon the whole, then, there is a want of proof that the disturbing forces were exerted through long periods beneath a given region, so as by many small and repeated convulsions, all operating in the same direction, to give the effect of one great dislocation. On the contrary we may believe, that the time was very limited during which several of the great dislocations and axes of disturbance assumed their respective characters. Yet, owing to the difficulty of the investigation, the question must in many instances be left wholly undecided.

The following Table shows the geological periods of many remarkable convulsions in Great Britain, and the places where some of the most considerable effects are manifested.

No.	Geological Period of the Convulsions.	Effects noted.	Localities of some of the Phenomena.
a.	During the deposition of the slate system	Production of argillaceous conglomerates	Derwent Water, Cumberland.
b.	Ditto	Porphyry and greenstone and trappean conglomerates	Grasmere in Westmoreland. Radnorshire, Herefordshire, &c.
I.	After the Cumbrian slates and before the carboniferous system	Disturbed position of primary rocks	The Grampians, Lammermuirs, Cumbrian mountains, N. Wales, Ocrynian chain, &c.
c.		Production of old red conglomerates	The Highland Border, Cumbria, &c.
1.	During the carboniferous period	Marine bed among estuary deposits	Yorkshire.
II.	Before the adjacent rocks of the saliferous system taken generally.	Numerous dislocations, fissures of dykes and veins, anticlinal axes, &c.	In all coal districts of this era, both in Europe and America. Charnwood, Crossfell fault, Craven fault.
d.	During the saliferous period?	Production of new red conglomerates	North of England, North of Germany.
III.	After, or during? the saliferous period?	Veins of lead, &c. Great or 90-fathom dyke	Yorkshire, Mendip hills, Tynemouth castle, Campsall, &c. border of Cumbrian group, (Kirkby Stephen.)
?	During the oolitic period?	Unconformity. Kelloway's rock in contact with the lower oolite group excluding the upper portion	Cave, Yorkshire, (p. 631.)
IV.	After the oolitic period	Unconformity of strata between oolitic and chalk systems	Yorkshire wolds, Dorsetshire cliffs.
2.		Estuary deposits. Pebble beds of lower green sand	In the Wealds of Kent and Sussex, Lincolnshire, Isle of Wight, &c.
	During the chalk period?	?	
e.	After the chalk period	Pebble beds, wasted surface of chalk	Hertfordshire, Vale of Thames.
V.	After the London clay	Vertical strata	Isle of Wight.
3.		Marine deposits between lacustrine beds	Ditto.
f.		The crag	Essex and Norfolk.

The Roman numerals are applied in the above list to all periods where considerable movements are traced in direct effects of dislocation and unconformity; italic numerals to those cases where a change in the nature of the water over given regions seems to result from a distant convulsion; and small letters to mark the occurrence of the most remarkable periods of conglomerates.

The next Table presents the result of a more extended survey of direct convulsive effects on the Continent and Islands of Europe.

No.	Geological Period of the Convulsions	Effects noted.	Localities of some of the Phenomena.
I. 1 and 2 E. de B.	Before the old red sandstone	Anticlinal axes and great faults of the slate system	The Hunsdrück and Taunus.
II. 3, 4, 5. E. de B.	Before the new red sandstone ... Before the rothetodteliegende ...	Immense disruptions and faults of the coal system	Calvados, South-West border of the Vosges.
	b. Before the zechstein.........	Immense dislocations and faults of coal strata	Westphalia, Belgium.
	c. Before the new red sandstone .	Immense dislocations and faults	Vosges, and Black forest.
III. 6. E. de B.	Before the lias.	Mountain ridges of zechstein, &c.....	Thuringerwald and Böhmerwald.
IV 7. E. de B.	Before the lower green sand.	Abrupt and distorted strata of oolitic system......................	Mont Pilat, Cevennes, (perhaps the Erzgebirge.)
V. 8. E. de B.	Before the uppermost chalk beds .	Abrupt elevations of green sand and lower chalk....................	Mont Viso, Devolny.
VI. 9. E. de B.	Before all the tertiary rocks.....	Elevations of chalk and green sand ..	Pyrenees, Northern Apennines, the Morea.
VII. 10. E. de B	Before the nagelflue	Detached ridges	Corsica, Sardinia, Auvergne.
VIII. 11. E. de B.	Before some diluvial beds.......	Newest tertiaries uplifted..........	The range of the Western Alps, Diablerets, Mont Blanc.
IX. 12. E. de B.	During the formation of other diluvial beds................	Some diluvial beds convulsed.....	The range of the Eastern Alps from the Valais to Austria.

Elie de Beaumont's generalizations.

It is to M. Elie de Beaumont that we owe the impulse which the study of the periods of geological disturbance has of late received, and he is the principal authority for the construction of the preceding Table. M. de Beaumont makes twelve distinct systems of convulsions which are supposed to have happened at as many distinct periods, but we do not find sufficient evidence to substantiate the division into five systems, of the first and second of our Table. The following is De Beaumont's view of these five systems including applications in Great Britain for comparison with the details of our first and second groups.

	N.	Geological Period of the Convulsions.	Effects noted.	Localities of some of the Phenomena.
I.	1	Supposed to be during the deposition of the slate, certainly anterior to old red sandstone	Elevation of many mountain chains without transition limestone.......	Grampians, Cumbrian group, Snowdon, Cornwall, Hundsrück, and Taunus, Isle of Man, Anglesea.
	2.	Posterior to the greywacke slate, anterior to old red sandstone...	Great faults affecting transition limestone, and anthracitic slates	Devonshire, South of Ireland, Bocage in Calvados, South-West border of the Vosges. Harz?
II.	3.	After the coal strata and certainly before rothetodteliegende.	Immense disruptions and faults of the coal	From Derbyshire to Northumberland along the Western border of Yorkshire, Malvern.
	4.	After the coal strata, certainly before the zechstein	Ditto..................................	Westphalia, Belgium, Mendip, South Wales.
	5.	After the coal strata, certainly before the bunter sandstein	Great disruptions.	Vosges and Black forest, from Basle to Mayence.

Direction of Convulsive Movements.

Elie de Beaumont's hypothesis.

It is impossible to make many observations concerning faults and other dislocations of the strata, without being strongly impressed by the fact that they commonly follow certain straight lines through a country, every where producing analogous mechanical movements. The length of their courses is often so considerable that one great dislocation defines the physical geography of a district. It has been long known that in mining Countries the faults take parallel directions, and sometimes two or more systems of dislocations, crossing in certain angles, were found to be of different antiquity. That dislocations were in some respects to be compared to the effects of earthquakes was also well understood, but no one before De Beaumont appears to have carried his notions of the coincidence between the lines of convulsion and the direction of the great physical features of the Globe, so far as to venture on the construction of a general system. This excellent Geologist believes that there is a constant dependence between the direction of the dislocation, and the geological epoch of its occurrence, such that all the dislocations of the same age are parallel to one and the same great circle of the sphere; and that, *in most instances*, dislocations of different ages are parallel to different great circles which intersect one another at assignable angles.

How to be examined and tested.

It will be readily understood that this general hypothesis is not to be tested by single or small dislocations. It must be examined on a great scale, by means of very exact and numerous data. It is not too much to assert, that in the present state of Geology, the facts known are not clear and numerous enough to support this hypothesis; and on the other hand there are not facts to warrant the unconditional rejection of it. It must be looked upon as a first attempt in a new field, as a generalization carried to extreme; but it is certainly founded on important data, and in several instances agrees well with observation. The principal difficulty of applying satisfactory tests to its consequences, arises from the uncertainty of the exact date of many of the most characteristic convulsions. We cannot positively tell whether the dislocations of the Grampians and Lammermuirs, which take parallel courses, were geologically synchronous or not, because the beds dislocated are not the same. Even in the case of the great faults which followed upon the carboniferous system, the limits of the geological epochs of their occurrence are too vague for the application of such a

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theory. In fact, De Beaumont's 3d, 4th, and 5th periods *may be* actually synchronous; so may his 1st and 2d periods be, because their *limits* are indefinite on the side of the least antiquity. Rothetodteliegende and magnesian limestone cover unconformably the coal of the North of England, and thus define the date of the convulsions; but in the South of England these are of rare occurrence, and often entirely wanting, and then the new red sandstone above the coal gives only a vague approximation to geological time.

At present these are irremovable difficulties. We can then, with strict propriety, only examine the question of the dependence of the direction of dislocations on the geological period, by comparing together, first, the directions of those dislocations which are *not* known to be of different ages; and second of those dislocations which *are* known to be of different ages.

Dislocations not known to be of different ages.

The first system of dislocations is vaguely limited as to time between some part of the primary strata and the base of the carboniferous strata. The direction of the axis of elevation of the Ross mountains, the Grampians, and Lammermuirs, prolonged into Ireland, is North-East and South-West. This corresponds with the general direction of the slaty rocks of Cumberland, the Isle of Man, North Wales, and Cornwall, of the Hundsrück and Taunus. But the direction of the Devonshire slaty rocks is nearly East and West; so is that of the South of Ireland, the Harz, the South-West border of the Vosges, and the Bocage in Calvados. M. de Beaumont thinks these two directions belong to two periods, the latter being more recent. This *may be* true; the hypothesis is not destroyed by the discrepancy, but we must demand clearer evidence of its truth.

The second system is more accurately limited than the former, since the series of rocks dislocated is generally more complete, and the undisturbed strata are of nearly the same antiquity. Three prevalent directions are recognised. The first is nearly North and South from the course of the Tyne to that of the Trent; it is parallel to the axis of the vale of Clwydd and to the chain of the Malverns. The second is nearly East and West, in South Wales and the Mendip hills, and along the Tyne; West North-West and East South-East in Charnwood forest; West North-West and East South-East in Craven; East and West in Belgium; East North-East in the valley of the Meuse and Westphalia; North-East and South West, or North-West and South-East in Shropshire and Radnorshire. The third is North and South, or North-West and South-East, from Basle to Mayence.

Some of these cases of discordant direction occur along the same dislocation, as, for instance, the great Belgian axis of disturbance from Westphalia up the Meuse and through France to Boulogne; in other cases the difference of direction *may* correspond to a difference of age: but this has not been proved, and ought not to be assumed.

Dislocations known to be of different ages.

We may now turn to consider the relative directions of dislocations of different ages. M. de Beaumont himself has found several instances of dislocations of unequal antiquity following the same parallels of direction. The North-East and South-West direction of the first system of disturbance is repeated in the fourth. (Seventh of De Beaumont.) The North and South direction of some dislocations of the second system (third of De Beaumont) is repeated in the seventh. (Tenth of De Beaumont.) We shall add some other coincidences. The East and West direction of the South-Wales coal field is the same as that of the great fractures along the Isle of Wight; the great Cleveland dyke of 70 miles in length, which cuts the oolites, is nearly parallel to the older elevation of Charnwood and the great faults in Craven. Again, it is a general law of most mining districts to have their principal productive veins running nearly East and West, and crossed by others North and South. Is it to be supposed that veins which are parallel are universally of the same age? Is it not very well known that they are not so?

These difficulties seem wholly insuperable in the present state of the Science. It seems not possible from elements so uncertain and confused to rise, by a legitimate process, to any sound conclusion, at once exact and universal in its application. Any hypothetical connection between geodesical lines and the directions of disrupted strata appears liable to interminable difficulty, from the excessive number and various direction of the dislocations. Any line drawn through any Country, not far removed from a great axis of disturbance, will be found more or less parallel to some of the cracks or faults which depend upon that axis. If, rejecting these minor phenomena, we limit our evidence to the great lines of mountains, the data are too few and too disjoined for satisfactory induction. To show by what evidence M. de Beaumont has himself been led to adopt his hypothesis, we may abstract his original account of two systems of disturbance, the one detailing minute, the other more general evidence.

Seventh System of De Beaumont.

Three small granite eminences in the Côte d'Or, near Sombernon, which accompany the disruption of Jura limestone there, range in a line North-East and South-West, parallel to the summit ridge of the Côte d'Or. The line of these granite points being considered part of a geodesical circle, and prolonged in each direction, is found to coincide with several remarkable geological accidents or disturbances. In the North-East, for instance, it coincides with dolomitic Jura limestone and steep dips at Suxy, between Langres and Dijon, with the hot springs and magnesian muschelchalk of Bourbonne les Bains, with the basaltic eminence of Essey, South of Luneville, and with the granitic protuberance of Albersweiler, between Annweiler and Landau.

Another line of disturbance parallel to the preceding is indicated, and it is observed, that from Paray (Saone et Loire) to Plombières, (Vosges,) the great line of valley watered by the Bourbonne and Saone is perfectly parallel. This line prolonged into Germany passes along the line of the valleys of the Mayn and the Saal, through Mittenberg to Leipzig, and is parallel to the Erzgebirge and Mittelgebirge.

Now all these dislocations were probably produced at the same geological epoch, which, though inferred from the general phenomena along the line, is determined more exactly in consequence of an extension of this system of faults by a series of parallels retiring to the South-East, till we arrive in the Department of the Rhone, where the Jura limestone and chalk occur together, the former dislocated, the latter undisturbed. The direction of these parallels of disruption is at Dijon, North-East and South-West. In the Jura a great number of undulations in the strata range parallel to a line North 40° East, or North 45° East, and, being sometimes filled with green sand deposits, are clearly of the same date as the other disruptions mentioned above.

The insulated chain of the Pyrenees, one of the most

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Ninth system of De Beaumont.

remarkable in Europe, forms the base of the ninth system. Many observations prove that the chalk and green sand are here uplifted with the primary rocks, but the later tertiary deposits lie level against their slopes, and some were deposited from a sea which washed the base of the already elevated mountains. The general direction of the chain, from Cape Ortegal in Galicia, to Cape Creuss in Catalonia, is a little South of East; but this general chain is composed of partial ridges whose axes are parallel to one another, and directed West North-West and East South-East.

This direction belongs to the disturbances of the same date in Provence and near Nice, and is recognised in the Apennines, at least in the Northern part, and in the Country of Naples, and along the South shore of Sicily. The South-Western boundary of the Nägelflue, in Swisserland, appears to correspond with the Pyreneo-Apennine line, as do likewise the Dalmatian and Croatian summits, the valleys of the Save and the Drave, the line of the Rhodopean mountains, and the ridge which crosses the Straits of the Bosphorus. Similar directions seem to be traceable in Greece; and as far as the evidence yet collected goes, the date of the elevation of all these chains is the same. The Carpathian range, parallel to the Dniester, falls into the same system with a small line of granitic and syenitic rocks along the Elbe near Dresden, and the mean courses of the metallic veins of the Harz.

Extending his views, M. de Beaumont finds some traces of the Pyreneo-Apennine system in Africa and Syria, in the Caucasus and the Ghauts of India; but the imperfect state of information concerning the Geology of these Countries renders the inferences concerning them of less value than those which relate to the North American mountains. On prolonging the Pyreneo-Apennine circles across the Atlantic by Hecla and Greenland to the New World, we find it descend parallel to the Alleghanies and their Northern connections, which have determined the form of the Eastern shore of North America; and, as appears by the statements of Transatlantic Geologists, were probably uplifted between the age of the chalk and the latest of the stratified rocks.

Such remarkable accordances of epoch and linear direction, over so enormous a length upon the surface of the Globe, cannot, says De Beaumont, be the result of chance, but of a regularly acting internal cause. Those who admit the generalization, usually imagine the effects to depend upon periodical fractures of the crust of the Globe through the cooling of its interior, so that the crust contracts convulsively with lines of fracture parallel to some great circle of the sphere.

More limited inquiry.

Relinquishing for the present any further attempt to construct a general system of relation between the age and direction of dislocations, we may still find it useful to inquire what laws of direction belong to dislocations in a limited district.

The remarks already made, pp. 543, 544, 597, 598, and in the Section on Mineral Veins, will render it unnecessary here to do more than state a single case of the parallelism of trap dykes, which has been furnished by Archdeacon Verschoyle, in the North-West part of Mayo and Sligo. (*Proceedings of the Geol. Soc.* 1833.) He describes no less than eleven basaltic and amygdaloidal dykes, which, in a space of 11½ miles in breadth, traverses the Northern part of the district in a nearly East and West direction, and cut through all the formations from the gneiss to the carboniferous limestone. One of these dykes he traced between 60 and 70 miles, and believed it might be followed much further to the Eastward. Two of the dykes are crossed by others having a North and South direction.

Direction of the Strata.

Mitchell's views.

It was long since remarked by Mitchell, that the direction of the strata in any region was generally parallel to the ranges of mountains; a truth of great importance in the modern system of Geology. The prevalent range of the strata in any Country must, however, depend partly upon another circumstance, *viz.* the original line of the Ocean boundary. In many parts of the Globe the most prevalent direction of the strata is observed to be North-East and South-West. Humboldt was so struck with these *loxodromic* lines in Europe, that he says one of his principal inducements to visit Equinoctial America was to examine the directions of the strata there. He has furnished evidence that the parallelism of the strata to the great lines of mountains, is a general law of Nature.

M. Necker's inferences.

M. Necker, in a communication to the *Société d'Histoire Naturelle de Genève*, has shown a very unexpected coincidence over large portions of the Northern hemisphere, of the direction of the strata, and the curves of equal magnetic intensity, as traced by Captain Sabine. One of these curves, that of 297 seconds, traverses Scotland in a direction North-East and South-West, which is exactly that of the strata; it keeps the same direction by Christiania in Norway, where, according to M. Von Buch's observations, the strata trend North-East and South-West, and pass through Sweden, where, according to Hisinger, the same direction of strata predominates. On arriving at the Gulf of Bothnia the magnetic curve turns North-West and South-East, which, according to Strangways, is the direction of the Southern border of the Swedish and Russian granite.

The curve of 308 seconds enters Europe by Lisbon, and passes South-West and North-East through the Spanish Peninsula, which is nearly the line of most of the long Sierras between the great rivers; it passes by the Cevennes, and goes parallel to the Alps in their North-East course to the Tyrol, but there turns South-East, as do also the lines of stratification through Carniola, Istria, Croatia, Dalmatia, and the Morea. Parallel to these are the Carpathian mountains. The same correspondence between the magnetic curve and the lines of strata is traced through the Crimea and along the Caucasus.

In North America the magnetic curve and the stratification range North-East and South-West along the whole Eastern coast; in the Rocky Mountains both extend from North North-West to South South-East: in Mexico the magnetic curve takes the parallel of the Cordillera of Anahuac North-West and South-East, and ranges along the South coast of New Spain. Further to the South the curves resume their course North-East and South-West, which, according to Humboldt, is the direction of the strata in Venezuela, and between the Orinoco and the Amazons. The mighty chain of the Himalaya, which in Nepaul bears North-West and South-East, and turns North-East at the North-East extremity of Bengal, is parallel to the curve of 297 seconds which was first noticed.

These remarkable accordances deserve the attention of Geologists, who must always receive with particular gratification any results tending to connect the general facts of the construction of the crust of the Earth with the laws

of the distribution of terrestrial magnetism, electricity, and temperature.

Effects of Convulsions in altering the Relations of Land and Water.

The submarine origin of the whole stratified crust of the Earth being admitted, and the actual elevation o these rocks above the sea in the existing continents being known, it is required to determine the several geological periods when different parts of the solid land were raised above the waves. It is usually taken for granted that this effect has been produced by the several systems of convulsions which have impressed angular movements upon dislocated portions near the surface of the Earth, and thus raised some portions and, perhaps, depressed others. That this general impression is frequently well founded, though it does not embrace the whole truth, will appear from the simple consideration, that the whole configuration of the dry land, whether in islands or continents, is dependent upon the direction and elevation of the chains and groups of mountains, which were certainly elevated, at various assignable geological epochs, above the ancient sea.

It may be asked how is this ascertained? The mere fact of those mountains being convulsed, and the strata therein thrown into angular positions, does not seem to prove that the region was elevated by such action above the level of the sea, nor, perhaps, that it was uplifted at all; since it may be imagined, with some theorists, that the neighbouring parts were depressed, and that the general level of the Ocean has been lowered. In answer to this we may proceed to show that the effect of the convulsions was relatively to raise the convulsed parts; that these parts were in several instances elevated above the sea at assignable periods; and that these effects were independent of any imaginary depression of the general level of the Ocean.

Elevation the consequence of convulsion

That the effect of convulsions has been, generally, to raise the convulsed parts will appear shown by considering what is the focus of the disturbance and the direction of its energy. The mountain chains and groups are most certainly the foci of the disturbing forces; for as we pass towards them, from all sides the number and force of the dislocations continually increase, and the declination of the strata grows more and more violent. The direction of the disturbing force is by the same process of observation clearly discovered to be vertical or nearly so, and outwards from the central regions of the Earth. It was an expansive force, which employed its principal efforts along certain lines and about certain centres, there breaking and bending the strata in the highest degree, but also lifting them up on all sides around. As far as we can judge, this elevation of the mountain chains and groups was generally unaccompanied by any neighbouring depression, for the inclination of the strata for the most part gradually subsides to a gentle slope, and finally vanishes in nearly horizontal planes. In the mountain chain itself, various and suddenly reverted dips may be met with corresponding to the violence of the disruption, but by a careful study of the exterior slopes the general tendency of the convulsion may be clearly deciphered.

The same data will not, however, by any means give us right to conclude that the mountains so uplifted were raised above the sea, because, though we may know the absolute height of the vertical movement, this will avail us nothing in our ignorance of the original depth of the water. We must examine to see whether they bear on any part of their surface any traces of those later marine deposits which spread around their bases. If they do, we may be sure they were not elevated above the sea till after the date of these strata; as for instance, the Alps, which bear upon their crests portions of oolitic, cretaceous, and tertiary strata, are thus proved to be of modern elevation. If they do not, and the newer marine strata around their bases have been deposited horizontally against the slopes of the mountains, we are entitled to believe that these had been previously reared above the sea. This conclusion, however, it must be always borne in mind, does not inform us correctly to what height they were reared above the sea, but leaves us to infer that they have since partaken of another movement by which these newer strata have been placed at their present elevation.

Speculations on the Ocean level.

The facility of escape from many embarrassing considerations which a general depression of the level of the Ocean seemed to offer, was too tempting to speculators in Geology to permit them to inquire into its physical probability. The simple question of what has become of the vanished water was disregarded by Werner, and perhaps never thought of by his followers. It will not now be sufficient to press it into a subterranean abyss, nor to carry it off to other planetary regions in the tail of a comet; we must admit that the quantity of water upon the Globe has been constant, or give up all pretence to philosophical moderation; and with this restriction upon our inquiries it becomes easy to prove that the level of the Ocean is confined within very narrow limits of fluctuation, so long as the Earth's axis and rotatory velocity are supposed invariable. If the level of the Ocean be expressed either by taking its mean depth, or the mean radius of its surface, this level may be supposed variable by reason of any local convulsive movements of the dry land or bed of the sea, any change of dimensions of the whole Globe, or any alteration of the mean temperature of the water. First of temperature. If we take the mean temperature of the Ocean at the Equator 81.5 F. its temperature at the Poles 0.0 F. on the surface, and at some depth (d) 81.5 F.; and suppose, in conformity with inferences from organic remains, that the whole surface of the Globe was formerly subject to a temperature equal to that of the Equator; the Ocean at that period must have been defined by a longer radius.

Variable with change of temperature.

The expansion of the Polar waters, supposing them to have been fresh, would be at the surface only to the extent of 4°.0, because at temperature 0°.0 F. fresh water occupies nearly the same space as at 77°.5; at nearly half the depth (d) it would expand through 42°.75, at the depth (d) nothing. Average expansion $= 22°.4$ which corresponds to $\frac{1}{184}$ of the depth. If we suppose d to be 10,000 feet, the Polar expansion $= 54$ feet. But if we suppose the water to have been salt, the expansion at the Polar surface, from 0°.0 F. to

$$81.5\text{ F.} = \frac{81}{180} \times \frac{1}{20} = \frac{81}{3600} = \frac{1}{44}\text{th}$$

of the depth: and at other latitudes

$$= \frac{1}{44} \times \text{sine lat.} \quad \text{And } \frac{10000}{44} \text{ feet} = 228 \text{ feet,}$$

which would give a mean rise of the Ocean $= 76$ feet.

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It is evident that such fluctuations of level, however real, are not adequate to explain the desiccation of large tracts of land.

What might be the effect of a general change of dimensions of the Globe, through variation of its own temperature, is beyond our power of investigation, because we do not know in what ratio the solid and liquid parts of the Globe would alter their dimensions.*

We may, however, consider the effect of a general change of dimension of the nucleus of the Globe, supposing the superficial temperature unaltered. According to all analogy of organic forms, the Globe may be supposed to have grown cooler continually, and thus to have contracted in bulk; but this, by shortening the mean radius, would cause the Ocean level to *rise* upon the land, which is contrary to the effect we wish to explain. If we even allow, for the sake of argument, an augmenting diameter to the Globe, this must go to a very great amount before the level of the Ocean, as compared to the land, would be sensibly affected. If the Ocean be 5 miles deep, the diameter of the Earth must be augmented $1\frac{1}{2}$ miles to cause the level of the water to sink relatively 10 feet, and to sink it half a mile the radius of the Ocean must augment 400 miles. It is unnecessary to prosecute this inquiry, for a sinking of half a mile would be insufficient for the desiccation of the whole dry land, even allowing the great mountains to have been uplifted.

Variable through intestine movements.

The most interesting part of the inquiry remains to be more carefully examined—the variability of the Ocean level in consequence of displacements of the solid land. We shall put the case in three forms, and according to each of these imagine the present continents to be depressed beneath the waters of the Ocean, as they once certainly were.

First, we may suppose no vacuum to exist below the crust of the Earth, nor any receptacle occupied by air or gases into which the solid land could sink, but that a sinking in one place should be compensated by a rising in another, so that the cubic dimensions of the Globe should remain unchanged. Moreover, to put the case to extreme, it may be a condition that the land shall sink so that water shall cover the whole surface. In this case the level of the Ocean would rise, that is, the mean radius of its curved surface would be lengthened, by a quantity depending on the mass of the solid land submersed, and on the relative area of land and water. This relation of area is about as 3 water to 1 land. The cubic content of the solid land may be thus estimated. In England, Wales, and Scotland, the average height of those conspicuous mountain masses which appear to give shape to the whole country is about 3000 feet; and if we consider this as the apex of a cone whose base is the given area, we shall have the cubic content of the mountain masses $= \frac{3000}{3} \times$ area. But on account of the valleys this quantity must be reduced to half, or $= \frac{3000}{6} = 500$ feet, and the area $= \frac{1}{2}$ of the whole area of the Island. In addition, the more level parts may be compared to a mean cone of 400 feet altitude, on an area $= \frac{1}{2}$ the whole area of the island. Then $\frac{400}{3} = 133$ feet, and making the sum of the bases = area of the Island, we have mean altitude $\frac{500 + 400}{4} = 225$ feet.

This principle applied to the Continents of Asia and America would give in round numbers about 1000 feet mean altitude of land; and as the area of the expanded Ocean would be four times as great as the land is now, the total mean elevation of the water, by the submersion of the whole mass of land, would be about 250 feet: a quantity too small to be of use in explaining any but the lesser order of geological phenomena, and which may be considered as the extreme limit of oceanic rise.

Secondly. We may suppose the existence of cavities into which the solid land might sink, so that there may be no elevation in another place corresponding to the given depression. To put this also to extreme, we may imagine the very improbable case that a mass of solid materials equal in bulk to all the solid land above the water, should sink into a cavity, and that the surface of the submerged land should be level. The level of the Ocean would be nearly unaltered, except in a small degree, by reason of its shallow expansion over the area of the land. We might go on to suppose even the enormously improbable case of cavities existing so large as to admit twice the whole solid mass of the continents, and that these should sink with an equal bulk of materials into these cavities. Even in this case the Ocean level would only be lowered 250 feet.

Thirdly. If we suppose contemporaneous or successive elevations and depressions however extensive, the Ocean level would oscillate about a constant line.

Conclusion adopted.

It is evident, therefore, that by no stretch of conjecture, that is not absolutely monstrous, can we torture the known laws of terrestrial arrangements into agreement with the hypothesis of any but small changes of the level of the Ocean; a conclusion of the highest value, since it enables us to argue upon that level as a general standard to which we may refer all the effects of internal movements, in whatever period, and by whatever forces produced. It must be remarked, however, that it fixes no limits to the effects of the temporary violence induced in the Ocean by such movements, because these effects would be proportioned to the impulse with which they were attended.

Gradual elevation of land.

It appears that we cannot in all cases understand the possibility of the elevation of land *out of the sea* by the mere effect of local convulsive movements, but must in addition admit the gradual rise of large tracts of land whether convulsed or not at some earlier epoch.* England is an unexceptionable example; and probably every Country will be found to require the same admission. The necessity for admitting this gradual elevation of the whole country, is first suggested by the difficulty of otherwise accounting for the altitude of the tertiary and other marine strata, which have been deposited long since the great convulsions which partially or completely raised the primary and other old systems of rocks, and are, in general, remarkably free from the traces of any such events. The older Geologists relieved themselves from this dilemma, by inventing the gradual diminution of the level of the Ocean; the moderns meet the difficulty by supposing a gradual intumescence of the land. The former mode has been proved to be incredible, the latter we certainly do not yet understand, but it is not at variance with the established facts of convulsive elevation.

Where convulsive movements can be traced in their

* Since this Section was written, Mr. Babbage has made known some very interesting views bearing on this subject. (*Proceedings of the Geol. Society*, 1834.)

effects we have a good local cause for the local elevation of the ancient bed of the sea; but where no such movements can be traced, and yet the land is raised far above the sea, it is clear that we must neither admit convulsion, nor deny the relative change of level of land and water. Now the areas of country which are elevated, but not convulsed, in such a way as to account for this elevation, are very extensive. The greatest portion of the level regions of the Globe is thus circumstanced. In many instances we might plausibly explain the facts by supposing that the same localities (as mountain chains and groups) which had been in very ancient periods liable to great convulsive movement, were during later periods influenced by more gradual and continual subterranean expansion, so as to bear up on their slopes the newer strata formed and in process of formation. This would apply to England, whose great centres of old convulsions are nearly confined to the Western borders, and it seems equally suitable to most Countries whose lines of mountains correspond with the general figure. The principle, once admitted however, will be found applicable to all situations, and equal to solve a very difficult class of problems in Geology. It may even clear our way through cases of alternate elevation and depression, such as the Temple of Serapis on the Neapolitan shore: for whatever be the cause of local intumescence, it may be discontinuous or intermittent, and elevation in one quarter may be counterbalanced by depression in another.

Proposal of a hypothesis on this subject.

But is such an assumption of local subterranean expansion consistent with what is known of the interior constitution of the Globe, or is it a vain speculation? So little is known of the interior of the Globe, that almost any hypothesis is safe from coming into collision with that knowledge, provided it allows of given mean density, and a specific gravity increasing toward the centre. Newton supposed the spheroid to be homogeneous; it has been found that this supposition is by no means necessary to fulfil the observed conditions of the problem of the Earth's figure, and the irregularities of attraction indicated by the pendulum experiments, and of curvature by direct meridional measures, seem to show that the *concentric masses* of the spheroid may *not* be of *uniform* density.

This being allowed, there would seem no objection to suppose that the densities along any one *radius* of the spheroid are *variable*, by reason of intestine movements among the unequally dense parts of the concentric masses, and this would exactly answer the conditions of the geological problem. For the length of any radius of the heterogeneous spheroid would necessarily vary with the densities; and considering the small proportion of the height of the land above the mean radius of the latitude, it is clear that small internal changes in a length of 4000 miles would easily account for variations on that line to the extent of 1000 feet or yards.

This *hypothesis* would give a gradual and prolonged elevation in some parts and corresponding depressions in others; it would not affect in a sensible degree the astronomical elements of the Planet, but would change more or less completely its hydrographical boundaries. It appears consistent with the inference to which we were conducted while studying the phenomena of mineral veins, (p. 777.) *viz.* that under the same region of stratified rocks different sorts of igneous rocks had been at different times developed; and at all events may be used as a first contribution toward a sound mathematical theory of general subterranean movements independent of volcanic convulsions.

We may now attempt a brief sketch of the relations of land and water in particular regions, during the successive geological periods, and notice the character of the agencies concerned in producing them.

It is sufficiently evident that we are precluded from any attempt to assign these relations generally, because we cannot know what tracts of land were once raised above the sea, and have since been submersed. This applies with great force to the periods, whatever they were, which preceded the formation of what we call primary strata; for concerning the question of the existence of land during those periods we cannot even offer a conjecture, except upon the basis of inquiries into the remains of terestrial organic forms imbedded in these strata. The evidence which they afford negatives, as far as it goes, the existence of land plants; but it is chiefly by the great extent and uniformity of character of these deposits, and by the absence from them in the lower parts of marks of littoral or fluviatile action, that Geologists might justify a belief that little or no dry land divided the wide primeval Ocean. We pass to consider the state of things during the primary period.

During the primary period.

It is admitted that the greatest effects of the elevatory movements which can be traced in the existing ranges of mountains were posterior to the primary deposits; but there are good grounds for believing that dry land in some (unknown) situations began to furnish vegetable reliquiæ, during, perhaps, the whole of the period occupied in the deposition of the clay slate system. *First*, there is the certainty that some disturbing effects of igneous agency are traceable among very old members of this vast group of rocks. (p. 571.) *Secondly*, the existence of carbonaceous matter (anthracite) among the newer slates. *Thirdly*, according to different authors, in the upper parts of the series occur various land plants.

At the commencement of the carboniferous epoch.

It is highly interesting to observe the coincidence of two classes of results bearing on the relation of land and water at this epoch. Some of the most extensive and important physical features on the Western side of the basin of Europe have resulted from convulsions *preceding* this epoch, which certainly raised out of the sea many remarkable ranges of high ground; and the most considerable accumulations of land plants which have furnished the substance of coal in Europe and North America, *followed* those convulsions. It may, perhaps, eventually be possible to derive, from the comparison of the local centres of elevation with the limited fields of coal, some conclusions as to the place and other circumstances of growth of the vegetables; at present we shall only venture three remarks. 1. The deposit of coal plants does not in general follow immediately, but after some interval, the uplifting of certain tracts of land; for between the uplifted primaries and the phytiferous secondaries, great thicknesses of conglomerates holding few or no plants, and beds of limestone full of marine shells intervene. 2. The plants which most predominate in the older parts of the carboniferous deposits in Great Britain (coniferæ) appear like the vegetation of a mountain district in a warm climate, while those which abound in the younger deposits of the same period (cactiaceæ, equisetaceæ, &c.) may be more successfully compared to plants of plains and marshes. 3. The coal basins appear related in position to the ranges of primaries uplifted before the deposition of coal, and not to those of subsequent ages. This is an important fact,

and must be further developed. On the Geological Map of the British Isles, (pl. i.) the local relation of the primary and carboniferous strata may be seen, and it will be observed that the latter form a broad belt parallel to the general course, entering into the indentations, and surrounding the insulated eminences of the former. But along the ranges of the Alps and Pyrenees, no such bands of carboniferous rocks occur. The British primaries were uplifted *before* the carboniferous period, the great European ranges *after*. Coal is, however, not uniformly spread over all the area of the carboniferous rocks. It occurs in the great valleys of the Forth and Clyde, *between* the Grampian and Lammermuir ranges, *in* valleys of the Lammermuir; (Sanquhar;) *round* the Cumbrian mountains; *round* the Welsh mountains; *in* hollows of the Anglesea primaries. Besides these remarkable juxtapositions, the long range of the great Northern coal fields is still partially united with the coal deposits encircling the Cumbrian and Welsh mountains; and it is only by the effect of immense subsequent convulsions, and the consequent unconformity of the saliferous formation, that it does not now appear completely united with them.

The immense coal deposits of Ireland are in the same way surrounded by primary strata, which were raised above the sea before the accumulation of the coal. Parallel to the Hundsrück and to the Taunus and Ardennes, which were elevated about the same early period, lie the coal deposits of Saarbruck, the Netherlands, and Westphalia. Comparing this statement with the inferences concerning the growth of the plants of the carboniferous period, (p. 594—597,) and with the peculiarities of the several coal fields, we seem to find a fair basis for reasoning concerning the original habits of fossil plants, which may eventually lead to important results.

Before the saliferous epoch.

The elevatory movements consequent upon the deposition of coal appear to have been very general and extensive, and in the basin of Europe to have materially contracted and altered the boundaries of the sea. In England, especially, this effect is clearly shown, by the rising above the sea of the large tract reaching from the Tweed to the Trent, and including nearly the whole of the space between Berwick, Carlisle, Liverpool, and Nottingham; thus forming a large and nearly united tract from the Pentland Frith to Cheshire. To the same periods we must refer a large augmentation of the previously elevated regions of Wales. It will thus appear that nearly all the Northern and Western parts of the Island of Great Britain were then raised above the sea, which still flowed over the sites of all the Midland, Eastern, and Southern Counties. The greater part of Ireland had also emerged. Besides these greater elevations, some smaller tracts, which now appear as detached groups of mountains, were then conspicuous as islands. Charnwood forest, the Dudley district, and Mendip are examples. The Cumbrian mountains were half surrounded by a sinuous arm of the sea, which washed the feet of the Penine chain from Kirkby Stephen to Brampton, expanded into the Southern Counties of Scotland, and perhaps connected itself along what is now a part of the Irish Sea, with a great diversified gulf in Cheshire, Warwickshire, Leicestershire. (See Map, pl. i.) To the East of a line drawn from Newcastle through Nottingham to Exeter, we may suppose it to have been all an open sea as far as the Ardennes and the Harz. It thus appears that some of the marking features of British and European Physical Geography are of very high antiquity; and however modified in detail, by subsequent internal movements and superficial wasting, their larger proportions and general effect in those early periods may be very well judged of from the characters which they retain at present.

It might appear that, during the saliferous period, the elevated lands nourished no great profusion of vegetables; for throughout the whole of Great Britain the magnesian limestone and new red sandstone system is wholly, or very nearly so, devoid of such remains; and though in a few places in Germany plants are found in some parts of this system, they rather confirm than oppose the general inference.

It does not seem possible to trace any close dependence of the local character of the saliferous system upon the circumstances of the Physical Geography of the region; for, correctly speaking, there is very little of *local* character, except what is imparted by the unequal extension of the limestone groups; and these are probably wholly derived from marine decompositions. Along the Vosges mountains, perhaps, a peculiar sandstone conglomerate may have been derived from these mountains.

Scarcely any thing in Geology is more remarkable than the great uniformity of appearance of such extensive deposits as those of the saliferous system, with such few remains either of marine or of terrestrial reliquiæ. The prevalent red colour of this system is of itself a circumstance of great interest, though of unknown origin. In many cases this colour is derived from a superficial coating of oxide of iron round the internally clear quartz grains; and there can be no doubt that chemical agencies were then in operation of a very extensive and very remarkable kind. It is difficult to avoid believing that the life of the marine mollusca and radiaria was much controlled by these agencies.

Before the oolitic epoch.

The deposits between the coal system and the tertiaries succeed one another so regularly in England, and even throughout Europe, that it is perhaps impossible to explain the successive parallel outcrops of the several strata, except by supposing a gradual elevation of the pre-existing land, or a gradual retreat of the Ocean. This problem becomes, however, still more intricate when we add the following general truths: 1. That in England the oolitic strata, which succeed the red marls, form hills of greater height than *any one point* of the saliferous formation; the same is true for Germany and France. 2. That there exist beyond the general range of the oolitic outcrops, many far detached hills of these strata resting on and overlooking broad plains of red marl, which seem to be in an undisturbed position. It is obvious in these instances that the surface has been subjected to enormous waste by the violence of watery currents; in every theory of diluvial or alluvial action it is supposed that these denudations were performed upon the dried and elevated land; but few speculators have had the boldness to attempt the solution of the difficulty, by assuming that the *inversion of relative level* between the red sandstone and the oolitic systems is wholly due to the wasting action of water.

Perhaps we shall best consult the true interests of the Science by not insisting much upon any mode of accounting for these yet insufficiently examined questions; but it seems right to observe, that a gradual elevation of the South-Eastern parts of England, parallel to the line of the oolites, and prolonged in duration through the whole period of the saliferous, oolitic, cretaceous, and tertiary rocks, would fully agree with the general physical features of the surface of the district, the minuter inequalities of

which may certainly be ascribed to superficial watery action. This view appears to agree well with the general character of the upper saliferous, oolitic, and cretaceous deposits, which exhibit many repetitions of analogous rocks and fossils, many deposits of limestone and clay, such as might be formed in quiet or deep waters, with but few beds of sandstone. From some of these local sandstones we learn the fact, that some parts of the land which borders the oolitiferous sea, nourished a variety of plants, characterised upon the whole by a predominance of vascular cryptogamia and coniferous phanerogamia, different from those of the older coal tracts.

Effects of Convulsions on the Deposition of Strata and on Organic Life.

The formation of extensive conglomerates has been already shown to be a natural consequence of convulsive movements; and it is in some cases very probable that the disturbance was centred in the immediate vicinity of these accumulations. But it would be a gratuitous contraction of a very interesting field of research to limit our inquiries into the effects produced by subterranean movements on the deposition of strata, if we did not take into consideration the peculiarities of mineral character belonging to the several systems of marine deposits, the alternations of marine and fresh-water rocks, and the successions of races of organic beings. What dependence there may be between these phenomena on the one hand, and subterranean movements on the other, will undoubtedly be revealed by the progress of inductive Geology, and results of a very interesting kind will flow from such a discovery. At present, we can only sketch a dim outline of a subject as yet scarcely emerging from obscurity.

Mineral Characters of the Systems of Strata.

Actual process of nature.

Sedimentary deposits, whether they are occasioned by the action of streams and floods from the land, or of tides and currents in the Ocean, have a mineral character depending on the nature of the materials acted upon. The same great stream may, according as its different feeders predominate in their action, deposit materials of different quality; there may be in such deposits effects depending on the season of the year, but all such differences are periodical, and a series of alternations of given mineral aggregates is the result.

The action of the tides in a certain direction, is also liable to periodical variations of intensity; the coasts worn by tides may be unequally affected at different times, and the accessions of materials from the land may be irregular; still these minute inequalities are almost wholly lost when we contemplate the average results of a long-continued course of the same tidal action.

Deep-sea currents, so long as they follow the same channels, can hardly be supposed to produce any but very uniform admixtures of sedimentary ingredients.

When, therefore, we find a series of sedimentary strata to consist of repetitions of the same materials, or of recurring alternations of different materials, the whole is reasonably referred to a series of the same, or similarly alternating effects of watery action upon the same tract of land, the same line of coasts, or the same channels of the sea.

On the contrary, the suppression of one class of deposits, and the production of another, clearly marks out to us that the water has ceased its action on the land, coast, or Ocean bed, which it formerly wasted, and transferred its attacks to a new quarter.

It was not the perception of these simple laws of modern nature but a clear recognition of their effects in older periods, that led Geologists to agree in classing together portions of the innumerable layers or strata into certain groups or formations, according as they are identical or analogous in their nature, very gradually change from one to another, or consist of a series of recurring mineral terms; and in dividing these groups at the points where new terms appear and old ones are suppressed. Thus the suppression of red marl, and the introduction of blue clays, marks the boundary of the saliferous and oolitic formations; the suppression of oolite, and the introduction of green sands, marks the limit of the oolitic and cretaceous formations.

No universal strata.

Whatever view we adopt of the origin of sedimentary rocks, there can be no doubt that, even from the earliest geological period, the bed of the sea must have been composed in different regions of different materials; this must have been the case, even if we carry back our thoughts to that remote epoch where we may suppose that nothing solid existed at the surface of the Globe, except the products of heat; for these, in fact, contain nearly all the varieties of minerals, and nearly all the elements of the composition of stratified rocks. The very earliest formations which we have yet succeeded in tracing, exhibit themselves in two very distinguishable masses; the gneiss and mica schist system on the one hand, and the clay slate system on the other. When, by the partial elevation of these rocks above the level of the sea, the Ocean was divided into separate parts, local differences of the sedimentary, and even chemical deposits, must speedily have resulted; and as the extent of land increased in any particular region of the Globe, the deposits in the residuary seas thereabout must necessarily have become more and more dissociated from those of other regions.

It is, therefore, very evident that there can be no universal strata; that during the greater part of the geological periods, rocks of very different nature may, and, indeed, must have been contemporaneously deposited; although, according to the circumstance of the cases, the peculiar products of one region may have been, by oceanic currents or other causes, mixed with those of another, and so a continual or interrupted analogy between the series of strata in each maintained.

Changing sediments connected with subterranean movements.

We have now arrived at the point when the coordination of the diversity of sedimentary aggregates in a given oceanic basin with subterranean movements, and the dependence of the former on the latter, may be presented in the form of a very probable inference. Geologists have long been accustomed, while reasoning on the phenomena of tertiary rocks, to recognise the principle of the dependence of the local difference between contemporaneous strata in different basins upon the physical structure of the region from which the materials of these strata were derived. It has been already shown that the successive diversity of strata in the same basin can only be understood by admitting that the different sediments were brought from different regions; it is evident that for this end the drainage of the land, the flow of the tide, or the direction of oceanic currents, must have been changed; this can only be ascribed to an alteration in the local relations of land and water, that is to say, to subterranean movements.

When this change of the sedimentary deposits is sud-

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den and complete, we may generally feel assured that it is owing to violent subterranean movements, which have opened a new communication with the basin; the exact *site* of the centre of convulsion may perhaps not be ascertainable, though in some particular instances the *direction* of the new currents may be inferred, and thence their local origin conjectured. When the changes of sediment are gradual or alternate, we must apply corresponding inferences with greater caution.

In some cases slight movements might accomplish great changes in the nature of the deposits. The map of the terraqueous Globe shows us how easily, at particular places, the waters of different oceanic *alvei* might be brought into union by the lowering of an isthmus or the opening of a strait. If the Mediterranean were connected through the Red Sea with the Indian Ocean, would not the deposits in each of them be reciprocally influenced? Such internal movements as might occasion this appear trifling when compared to the disturbances which we know to have been many times effected within the range of geological chronology.

Successive Races of Marine Animals.

Local change of organic races.

If, in consequence of internal movements, a given basin was opened to the reception of currents and sediment from a new quarter of the Ocean, it could scarcely happen otherwise than that a change should arise in the inhabitants of that basin, by the extinction of some, and the introduction of other species. If we except the earliest series of fossiliferous deposits, there is nothing in Geology to indicate that the distribution of species over the Globe was regulated by different laws from those which now prevail; the superficial temperature of the Globe was perhaps more equable, and for this reason organic forms might be more extensively distributed, there might be *less* local distinction than at present, but yet each species had its definite boundaries, and different regions were characterised by peculiar races.

Upon the establishment of a communication from one such region to another, there must necessarily be a *tranference* of organic life, at least in one direction, according to the locomotive habits of the creatures, and the influence of currents upon them and their ova, and other circumstances.

It was with this in view that the passage (p. 553.) relating to the succession of races, corresponding to successive deposits, on a given part of the Ocean beds, was written.

How remarkable is the coincidence of great convulsions, decided changes of mineral aggregations, and substitution of new organic remains, needs only to be mentioned; for these three orders of effects are all combined in modern Geology to characterise the groups or systems of stratified rocks.

Fresh-water and Marine Alternations.

Few geological phenomena declare more plainly their dependence upon ancient convulsions than the alternations in a given basin of strata, of fresh-water and marine deposits. Not that in every case where we see fluviatile or even lacustrine shells alternating with marine exuviæ, we must suppose the levels of land and sea to have been changed, because at the mouths of some rivers this might happen from the bursting of a lake, a violent inundation, or even the natural course of things; but when, as in the coal field of Yorkshire, over the marine deposits lies a great mass of matter derived from the land, and in this a particular layer of marine exuviæ; when, as in the Weald of Sussex, we observe above the marine deposits of the oolites a great thickness of fluviatile deposits covered by marine green sands; or, as in the Isle of Wight and the basin of Paris, see really lacustrine marls and limestones interposed among really marine strata; the conclusion seems inevitable that these are effects of changes in the relative level of land and sea. It would, however, be too much to assert in every case that the internal movements *were centred* near the places where we witness some of the effects; on the contrary, we may perhaps probably often be merely looking upon the consequences of convulsions which happened at great distances of space, and which produced near their centres of action wholly different phenomena. This mode of interpretation applies very well to those instances in which repeated alternations of marine and fresh-water productions occur without any indications of corresponding local disturbance. (See p. 591.) As an example, we may cite the marine lacustrine formation of the Isle of Wight. (p. 674.)

The Weald of Sussex.

Application to a case proposed by Mr. Lyell.

One very obvious effect of convulsive movements, whether sudden or gradual, must always be a more rapid rate of waste, both in the land and along the coasts, than usual. It will, no doubt, be possible hereafter to draw from the *varying rate* of sedimentary aggregation in a given basin, some important evidence concerning the amount and duration of the internal movements which caused a more than ordinary accumulation of materials in the sea.

By combining with this the results of an inquiry into the local site of the convulsion, as inferred from the direction of *new sediments*, we may eventually be able to point out, with more or less probability, the original sites of these materials, and thus show how in ancient periods the wasting of one given tract of elevated rocks, has contributed materials for the accumulation of new deposits in the sea.

So long as, in the prosecution of this research, we confine ourselves to the methods of the inductive philosophy, our progress will be real though slow; new circumstances will arise to quicken the process and solidify the results, and light will gradually break in upon the yet obscure problem of the physical geography of early geological periods.

Mr. Lyell's persevering investigations into the history of the tertiary strata have produced a very remarkable attempt to determine the local origin of the materials of the English tertiaries, and the local seat of the corresponding subterranean disturbances.

The geographical relation of the anticlinal axis of Sussex and Hampshire to the tertiary deposits on either slope, has long fixed the attention of Geologists: it was proved by Dr. Buckland, that the tertiary basins of Hampshire and London were once, at least, partially connected; it was known that the first deposits above the chalk were such as to indicate prolonged action of agitated waters, that the subterranean surface of the chalk was uneven, and that among the tertiary deposits were abundance of pebbles apparently derived from water-rolled chalk flints.

Mr. Lyell supposes that " the chalk of the South-East of England, together with many subjacent rocks, may

have remained undisturbed till after the commencement of the tertiary period. When at length the chalk was upheaved and exposed to the action of the waves and currents, it was rent and shattered, so that the subjacent secondary strata were exposed at the same time to denudation. The waste of these rocks, composed chiefly of sandstone and clay, supplied materials for the tertiary sands and clays, while the chalk was the source of the flinty shingle, and of the calcareous matter which we find intermixed with the London clay. The tracts now separating the basins of London and Hampshire were those which were first elevated, and which contributed by their gradual decay to the production of the newer strata. These last were accumulated in deep submarine hollows, formed probably by the subsidence of certain parts of the chalk, which sank while the adjoining tracts were rising." (*Principles of Geology*, vol. iii.)

Without following the range of ingenious arguments employed by Mr. Lyell in fortifying his hypothesis, we shall notice the facts which seem most clear in their evidence, and which can be interpreted without theoretical assumptions.

Circumstances favourable to Mr Lyell's view.

1. It is certain that the Wealden Country, with some other tracts in the South of England, has been uplifted by subterranean movements, independent of that general rise of the whole of the Eastern part of the Island before adverted to. (p. 788.) Whether this was accomplished by one or many successive movements cannot be decided by direct evidence; it would appear, however, that the convulsion was not ended till after the deposition of the whole marine tertiary series.

2. It is undoubted that the upper secondary strata disclosed in the Weald once extended much further towards the central axis, and have been exposed to enormous waste and denudation. There is nothing to negative the opinion adopted by many Geologists, that the whole of the area inclosed between the North and South Downs was once completely covered over by the chalk and the subjacent green sand system; but this admission is not really necessary to the hypothesis.

3. The tertiary basins on the Northern and Southern sides of the axis of elevation of the Weald, contain nearly the same kinds of sedimentary deposits in the same order of succession, so that both of them must certainly have been influenced by the mechanical agency of water, flowing under nearly the same conditions, from the same physical region, or from regions consisting of the same materials equally exposed to aqueous erosion.

4. The materials of the tertiary strata, in the basins of London and Hampshire, are analogous to those which have been removed by denudation of the Weald; since they consist of various coloured sands, which may be imagined to be derived from the green sands and Hastings sands, and of clays which may be supposed to have been furnished by the Gault and Weald clays, and contain pebbles which are allowed to be rolled chalk flints.

If we could venture to add to these statements, that the *order of succession* among the strata of the tertiary series was exactly that of the successive emergence of the chalk, green sands, Weald clays, and Hastings sands, the hypothesis would stand on much firmer basis than is afforded by the above favourable circumstances. After an impartial consideration of the case, we have not been able to trace such a clear dependence of the successive members of the tertiary series upon the nature of the secondary strata successively wasted, as is implied in the hypothesis, that the gradual wasting of the Weald has furnished the materials for the gradual filling up of the basins of London and Hampshire.

Chalk, the secondary stratum liable to be *first* wasted, and consequently to yield the materials of the lowest tertiaries, has furnished only a mass of flints interspersed among the variegated sands and clays, (with very little calcareous matter,) such as might claim origin from those strata of the Weald which were the *last* to undergo the influence of littoral agitation. The lower group of the Weald should have left a predominant mass of sands above the other deposits in the tertiary basins.

It may be replied, in favour of the hypothesis, that the fine particles of chalk might remain suspended, or be entirely dissolved in the water, until the period of the formation of the London clay, which is partly calcareous; that the coloured sands associated with flint pebbles were derived from the green and iron sand groups; and that the uppermost deposit of the tertiary groups may have consisted of sand which has since been removed.

Principal objection to it.

Perhaps the most formidable of this class of objections is the *total and absolute* deficiency of any of the organic remains of the Wealden rocks (except in rolled chalk flints) in any of the tertiary deposits in question. This applies especially to the tumultuous deposits of sand and shells which lie above the chalk; for here surely some of the numerous organic fossils of the green sand system, or some few fragments of the rocks, of the Hastings sands, with plants, shells, or bones, should have been found.

Some recognisable specimens of the shelly marbles of the Weald clay ought, in some one locality or other, to have been discovered in the argillaceous beds which form a predominant feature in the tertiary basins. If it be remembered, that we are here speaking of very contiguous districts; that the distance which the materials can be supposed to have been removed is only a small number of miles; and that it is matter of common observation, that by some currents or other, whether diluvial or alluvial, of transient or prolonged duration, vast quantities of organic remains, separate, or imbedded in recognisable masses of sandstone, limestone, shale, and ironstone, have been drifted fifty or one hundred miles; it must be allowed that the total absence, from the tertiary strata, in all situations yet examined, of any fragments of the Wealden rocks or fossils, is a very serious difficulty to the reception of an hypothesis which derives the one from the other.

General View of the State and Prospects of Geology.

A review of the preceding pages offers abundant proof that Geology has *escaped* from that critical stage through which all Sciences, founded on observation, must pass—the stage of speculation and dogmatism. If it has not yet arrived at the dignity which is conferred upon Inductive Science, by the establishment of very general laws, binding together a mass of dependent phenomena, it is enriched with many valuable generalizations, provided with powerful means of further investigation, and guided by distinct landmarks over a wide field of original discovery. Geology is dissociated from Cosmogony, and we are no longer made to perplex our minds with "thoughts beyond the limits of our frame," no longer required to accept an explanation of natural phenomena, founded on a violation of the laws of Nature. Leaving the impossible problem of the creation and first disposal of the matter of

the Earth to those who may think there are means of solving it, but ascending beyond the short annals of the human race to the contemplation of the earlier epochs of the World, Geologists endeavour to discover the series of revolutions which have affected the Earth, by deciphering the monuments which they have successively left.

Men may be as soon reclaimed from barbarism, and raised to the summit of civilized excellence, as philosophers induced to abandon the sweet paintings of theory for the hard outlines of fact; and though in the successful career pointed out and followed by the Geological Society of London, the principle of fact before theory has been generally acted upon, it is difficult to repress the impatience which would rather mingle truth and fiction in a bold conjecture, than patiently separate the gold from the dross by the regular process of analysis. The opinion has been expressed by high authority, and seems to be gaining ground, that the time is arrived for the intervention of theory, to arrange the vast mass of facts which at present constitutes positive Geology, and to indicate the lines of further progress toward higher points of knowledge. It is, however, to be supposed, that few will obey this premature call for theory, who are aware of the many unfinished inquiries and vague generalizations which must be settled before even a prudent speculator would venture to commit himself to the tribunal of Inductive Philosophy.

State of geological theory.

We have now assembled many data for a theory; but in the very labour of collecting them, men have gradually acquired what is more valuable, a habit of limited generalization, and of continual appeal to the progress of collateral evidence in unfolding the laws which govern material nature, which at once restrains the presumption of the writer and the credulity of the reader. Under these circumstances the progress of the Science is not doubtful, and all that can be reasonably attempted toward the foundation of a theory of the Earth, is a review of the bearing of the facts already ascertained, on some of the leading problems involved in geological speculations: we shall thus learn what knowledge we have gained; what inferences it will support; how that may be augmented, and these corrected.

Lapse of Time. Geological Chronology.

All the thoughts of men are so inseparably associated with the idea of succession, that the knowledge of any physical fact is never satisfactory unless the *time* of its occurrence be given. The historical period of an occurrence is determined by reference to other events, whose place in the series of recorded human actions, or natural processes, is known. The chronology or fixing of the year in which any event took place is an admirable contrivance, the fruit of enlarged Science, which has found the means of referring all historical events to an independent and permanent natural scale, the movements in the Solar system. No person proceeds many steps in Geology, without feeling the want of some historical scale of successive phenomena, in which to interpolate new terms of the series; and though this want is to a certain degree generally, and for particular regions of the Globe perfectly, supplied by tables of the superposition of strata, we still find ourselves impelled to attempt the reduction of this historical series to the independent scale of chronology.

This difficult problem has never been fairly entered upon, except in the particular case of the diluvial and alluvial deposits. Those who admit the identity of the diluvial currents of Geologists and the Noachian flood, and suppose, with Cuvier and De Luc, that this was "the last great revolution affecting our Globe," may be expected to feel some anxiety as to the number of years which, on natural, that is to say, geological evidence, can be reasonably supposed to have elapsed since that event. In such inquiries the growth of the deltas of the Nile, the Po, and other rivers, the movement of the sands of Libya, the excavation of river-courses, may all be employed according to the views of the writer. Always it is to be remembered, these calculations admit as a principle the uniformity of natural superficial agencies since the diluvial period, and that period is geologically defined with more or less certainty; from such data consistent results seem attainable. There are, however, difficulties in estimating the amount of mechanical effect performed, not easily overcome. In the case of a delta, the materials may have fallen into water of unequal or unknown depth, and have been exposed to waste by currents of variable force; the movement of sands must be yet more capricious; the time employed in the recession of the falls of the Niagara from Lake Ontario to Lake Erie, has been estimated by Mr. Lyell at 10,000 years, by Mr. Fairholme at 5000; five or six thousand years is the vague conjecture, rather than conclusion, of Cuvier, of the time elapsed since the "last grand catastrophe;" and in general it must be owned that the methods of arriving at these conclusions have very little of accuracy to recommend them.

Superficial deposits.

Those Geologists who admit the excavation of valleys by a force of water greater than what now passes down them, may take the date of the denudation of these as an era, and compute the time elapsed in the subsequent excavation of the river bed, in the partial or complete filling up with sediment of lakes along its course, and in the retrocession of waterfalls along the main or branch streams. Few persons, however, who value an arithmetical result for its precision, will proceed to the calculation without more information of the *rate* of these operations than is at present attained.

The fossil elephant, and other animals whose remains lie buried in gravel and other deposits called diluvial, belonged to a system of organic life, which, for some limited period prior to and during the era of those deposits, was established over a large part of the surface of the Northern hemisphere. This is termed by many Geologists the antediluvial period; some intending by this, nothing more than to mark its relation to the era of the "diluvial" currents, thus adopting the term from comparison with Scripture History. This is, properly, a terrestrial period, and we have shown the difficulty of defining its limits towards the tertiary period, which is, properly, a marine period. (p. 671.) The lacustrine tertiaries here become almost our only safe guides, and they teach us that during the tertiary period an earlier group of extinct animals, the palæotheria and their congeners, inhabited the same tracts of the Globe, as those which afterwards nourished the mammoth and mastodon. We are absolutely without any means of estimating in years the length of the interval between the era of the palæotheria buried in the Paris basin, and that of the elephants which are entombed in gravel deposits. The small extent of alluvial and lacustrine deposits of this period may perhaps justify a conjecture that it was of short duration, as compared to the postdiluvial period; but this view must

not be adopted by those who attribute to the diluvial currents the excavations of valleys and other extensive alterations of the surface; because such a deluge would sweep away most of the traces of antediluvian lakes.

If the difficulties experienced in attempting to chronologize the terrestrial phenomena of the later geological periods have been sufficient to deter nearly all prudent and exact writers from venturing to give more than an illustration of the kind of reasoning to be employed, it is no wonder that for the long series of successive marine strata the attempt has been almost absolutely abandoned. It is doubtful whether we ever shall arrive at more than plausible inferences concerning the *time* elapsed in the production of the stratified rocks; yet as the consideration of this subject can be prosecuted in a strictly philosophical spirit, by the help of several satisfactory analogies, and as at all events the historical succession of the phenomena is either perfectly known or capable of becoming so, it appears an equally useful inquiry as that relating to the subsequent terrestrial periods.

Old stratified deposits.

To determine the length of years required for the deposition of all the stratified rocks under the circumstances in which they are observed, requires a knowledge of the number of repetitions of similar phenomena, and of the *rate* of their occurrence. In the Geology of stratified rocks several independent series of phenomena occur, each of which may be subjected to this examination. Of these we may notice:—

1. The mechanical deposition of sands, clays, conglomerates, &c.
2. The chemical deposition of limestones.
3. The periodical alternations of the laminæ or strata of clay, sand, limestone, &c.
4. The growth and decay of organic beings then living in the sea.
5. The successions of races of organic beings in the same parts of the Ocean.
6. The succession of convulsions.
7. The alternation of marine and fresh-water productions.
8. The alternation of marine and igneous products.
9. The metamorphism of rocks, fossils, &c.

1. Mechanical deposits of sand, clay, &c., take place only in consequence of degradation or waste of some region of the Globe, followed by a removal of the materials to some place of comparative tranquillity. Intermitting actions of this kind usually produce laminated deposits, and if the materials be of different kinds these may alternate in the sediment. In some valleys, every inundation leaves a thin layer of sediment; the number of inundations might thus be counted since any given date, and the number of years nearly ascertained. Analogous effects happen along those coasts where the tides deposit sediment; we see the same effects in many of the sandstone and clay strata which were accumulated in estuaries.

Some of the flagstones of the coal measures are composed of frequent alternations of rolled grains of felspar, quartz, and mica, which may be estimated to occupy not more than one-twentieth of an inch in thickness. Taking the thickness of the rock at 40 feet, we shall have 9600 layers, each of which marks *an interrupted action.* Let this be supposed to be the tide, allow that every tide deposited one layer, equal to about 700 per annum; this will occupy 13½ years. As far as we can ascertain, the other sandstones of the coal tract were accumulated in the same manner, though only a few of them are micaceous enough to show this minute lamination. The thickness of the Yorkshire coal measures is about 3000 feet, half of this may be considered as sandstone equal to 1500 feet, which, according to the above calculation, might be deposited in about 500 years. If we suppose the accumulation of the alternating clays to have been at the same rate, (there is good reason to admit this,) the whole period occupied in the deposition of the coal measures would be 1000 years.

Mechanical deposits.

It is perhaps unnecessary to say, that the assumption of each lamina marking the action of one tide is perfectly gratuitous, and has been adopted merely to give a specimen of the mode of calculation which must be employed if we wish to state the probable extent in years of a given geological period. Conglomerate rocks present a most convincing proof of the considerable periods which sometimes intervened between the deposition of two stratified rocks in contact and immediately succeeding one another. These rocks of turbulent origin are locally distributed, so as to be in some parts enormously thick, and in other places almost or entirely deficient. The old red sandstone conglomerate, for example, usually separates by a great thickness the greywacke slates from the superincumbent carboniferous limestone. In Herefordshire and Radnorshire, this series of red sandstones and conglomerates is many thousand feet thick, but in the greater part of the Cumbrian mountain tract it is absent, and the limestone and slate are in contact. In this case, it would be a great error to suppose the deposition of the limestone to have been immediately consequent on that of the slate. In fact, that very district gives proof that a period of violent watery tumult intervened, during which the slate rocks were broken up and rolled to pebbles, and reconsolidated into a thick conglomerate. The rate of this process can only be conjectured, by comparison with the production of pebbles by the diurnal processes of tides, rivers, and local inundations. When, as in the Rigi, we find rolled masses of conglomerate containing rolled pebbles; in the old red conglomerate of Cumberland masses of the preconsolidated slate; in the new red conglomerate of Westmoreland fragments of the mountain limestone with organic remains which have undergone *their usual chemical conversion;* enough is known to prove, to a mind not wholly blinded by false views of Science, that the monuments left for Geology to decipher carry back the History of the Earth to periods when man and his works existed only in the long foreknowledge of his Maker.

Chemical deposits.

2. Chemical deposits of limestone.—It is difficult to fix upon any method of estimating in years the time required for the deposition of a given mass of limestone. It is useless to refer to instances of the production of limestone from springs, in fresh-water lakes, in estuaries or coral reefs, unless the circumstances under which the older calcareous deposits were made are similar, a case seldom to be proved. The following process, founded on the statements in p. 551, appears the least objectionable.

It is certain that while the sandstones, shales, coals, and thin oolitic limestones of the North York moors were deposited upon the lias, a deposit almost wholly calcareous was occasioned near Bath. The whole time consumed was the same in each locality; we may therefore perhaps infer the comparative rate of deposition of the oolite and the sandstones. The total thickness of the mass in Yorkshire is about 750 feet, of which about 20

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may be called limestone; of that near Bath 180 of which nearly half is sand and clay with calcareous matter interspersed. Hence we have the proportion of three feet of sandstone deposited in the same time as one of limestone.

Another instance is afforded by comparing the sections of the lower carboniferous limestone, in Derbyshire and in Tynedale. In the former tract we may take 750 feet as the thickness of limestone, with no admixture of sands or clays; in the latter, the contemporaneous strata are at least 1750 feet thick, and contain 367 feet of limestone, and 1283 feet of sands and clays, &c.; consequently, 383 of limestone correspond in time to 1283 of sands, clays, and coal, or 1 to 3.3.

3. Alternation of chemical and sedimentary deposits.—There is undoubtedly a periodicity in these alternations, but we are not yet in a state to draw any inferences, as to the cause of the recurrences, much less as to the length of their periods.

Organic remains.

4. Imbedded organic remains.—In viewing the shells distributed in rocks, we sometimes perceive, amongst a large collection of them from a given stratum, a complete series of forms from the youngest to the full grown shell; and this may be a means of calculating the lapse of time during the accumulation of a given thickness of rock more exactly than by any other. A thickness of calcareous shale, not exceeding one foot in the Yorkshire coal field, holds individuals of ammonites Listeri of every magnitude between a pin's head and an orange; it is not to be doubted that they lived where they are found; and as not one example of this species is known in any other stratum in the neighbourhood, it seems correct to admit that, during the deposition of that small mass of shale, so much time elapsed as to allow of the growth to full maturity of a long-lived cephalopode. The only other supposition which can be entertained, is that they were introduced alive by a transient irruption of the sea into a fresh-water basin, and there quickly entombed.

It is to be regretted that the age of shells has been very little inquired into among collectors. Both conchifera and mollusca are probably, in general, long-lived animals.

The immense number of shells occasionally buried in a rock is sometimes appealed to as a proof of the length of time consumed in its production; but this is a very unsatisfactory argument. Those who have witnessed the amazing increase of cyclas rivicola in the canal near Leeds, or of uniones and anodontes in many sluggish rivers near the tideway, have walked among the numerous shells on the coast of Ayrshire, or the crowds of tellinæ thrown upon the Filey sands by a single tide, will not permit to Geologists the use of such a fallacious inference. This immense abundance of fossils is often a local phenomenon in the rock, and one which, when better understood, will aid materially our conceptions of the agencies which were concerned in its accumulation.

The nearly vertical position of certain fossil plants, a phenomenon by no means rare among sandstone rocks, affords good ground for caution in assigning very great extension of years to geological periods. The stems of equiséta in sandstone of the oolitic era, (page 625,) of sigillaria in sandstone of the coal series, (page 596,) of dicotyledonous wood in limestone of the Isle of Purbeck, seem to teach us in plain terms that the accumulation of these rocks was not of that slow and insensible kind which is often attributed to them. Whether we suppose them to be in their place of growth, or to have been swept down to their present situations by land floods, the result as to our present argument is the same; the accumulation of transported sediment must have been so rapid as to prevent the decomposition of the cortical portions of the plants, the wearing away of the superficial structure, or the bending of the stem beneath currents of water. No one doubts that the bed of stone three feet thick, which encloses equisetum columnare at High Whitby, was laid by a single inundation; we will suppose it an annual occurrence; the other sandstones and shales of this series must have the same rate of origin ascribed to them; this would give for the formation of the oolitic sandstones and shales in the North York moors a period of 150 years. About the same, or a slower rate of formation, may be supposed for the case of sigillaria in the coal sandstones of Yorkshire; for these stems, when above two or three feet long and nearly vertical, pass through more than one, sometimes four or five beds of stone. (Altofts near Wakefield.)

Successions of races.

5. Successions of races of organic beings in the same parts of the Ocean.—The succession of different races of organic beings in the same parts of the Ocean, is one of the leading facts which speak the most impressive, though not the most exact, language on the subject of the long duration of geological periods. For, whether we consider those cases in which the extinction of old and the introduction of new species was gradual, or others when the changes were sudden and complete, nothing that we know of the actual constitution of Nature will justify us in admitting that these revolutions in the animal world followed quickly one after another. We are impelled to conclude that, for the existence of any given race, consisting of thousands of individuals of many hundred species, imbedded in many different kinds of rock, in distinguishable groups according to their habits of life, a long time must be allowed, or else the whole constitution of Nature was in a state of forced acceleration, so that the work of ages was crowded into years. Whether we suppose that new species were contemporaneously created in all the situations where they lived and died, or distributed from one local origin over the sea, or transported by currents from other oceanic centres of life, no one who considers the stability of the actual system of watery life, will be easily persuaded to believe that these prodigious changes were operated over a large part of the Globe in times that can be included within such narrow limits as those of human experience. Yet who will venture to translate the vague and almost poetical visions of long duration, which the contemplation of many repetitions of these local revivals of Nature so powerfully awakens, into the language of chronology? It is evident that the day is not yet arrived, or rather it is gone by, for dogmatizing about the antiquity of the crust of the Globe.

6. The successions of convulsions in the same physical region may be very properly mentioned as a vague indication of the lengths of geological periods; but cannot at present be employed in a more exact manner to determine their duration.

7. The alternation of marine and fresh-water products is another of those grand phenomena, which, whether rightly or not, is sure to make a deep impression on the mind; though the rarity of the case, and our ignorance of the principal efficient circumstances, must wholly exclude it from among the data for accurate calculation of geological time.

8. The same may be said of the alternation of aqueous and igneous products.

9. The metamorphism of rocks, &c., in consequence of the local or general effect of heat, may possibly one day be sufficiently understood to permit some attempt towards determining the intensity and rate of the communication of heat, and thus more or less directly bear upon the question of time. The chemical changes of organic remains are evidently less related to time than to other circumstances, such as, the original nature of the body, the sort of substance in which it is imbedded, and proximity to sources of mineral impregnation, whether by aqueous or igneous solution, or electrical transfer of solid ingredients.

Successive Conditions of the Globe.

The object of geological researches has been till lately very little understood by those not directly conversant with the subject; and even professed Geologists do not always restrict their inquiries within just bounds. It is difficult for a speculator to believe that Geology may become a very important branch of natural Science, though it should wholly disclaim the investigation of problems concerning the creation or concentration of the matter of the Globe, or the establishment of the laws of the universe. To know the successive changes which the Globe has undergone, and thus to trace a retrospective outline of its successive conditions, is actually attempted by Geology; but the very processes employed in this enterprise are founded upon the recognition of the existing laws of Nature, and altogether exclude the popular notion of a chaos, and the philosophical hypothesis of a solid Globe condensing from an atmospheric expansion.

Undoubtedly the progress of legitimate Geology teaches us that the same laws of Nature have operated on this Globe under very different circumstances, as to temperature, relation of land and sea, animal and vegetable life, and many other things; and it is become a proper problem for Geology to discover these circumstances. In this point of view, the reflections of Leibnitz, and the mathematical labours of Laplace and the astronomers, become of great value, since they help to fix conspicuous landmarks for the guidance of the surveyors in this large field of Science; but let no one delude himself with the notion of discovering, by geological processes, the emerging of the harmoniously adjusted terraqueous Globe from a former state of chaos. It is certainly not a philosophical, and surely cannot be thought a religious notion, that man shall ever discover among the works of God, the traces of a period when his divine attributes were first awakened to rescue his creation from anarchy. Geology takes for granted the existence and collection of the matter of the Globe, with its supernatant Ocean, and its enveloping atmosphere. Except in the degree of influence which circumstances permit them to exert, it takes for granted the uniformity of action of all material causes. The investigation of miracles can never be admitted into natural Science.

The dimensions of the Globe have remained constant since the days of Hipparchus; (born 160 B.C.) for Laplace has shown that the length of the day has not sensibly varied since that time, which must have happened if the diameter had perceptibly changed: if the Globe had contracted, the diurnal period would have been shortened, and *vice versâ*.

This is usually considered a very formidable argument against the doctrine of internal heat, and its corollary, secular refrigeration and contraction, to which theorists have very freely resorted, as the prolific source of all subterranean movements, changes of superficial temperature, elevation of continents, volcanic eruptions, injection of igneous rocks, mineral veins, &c. Fourier's researches, however, into the mathematical theory of heat, show that, under the conditions of sensible constancy of dimension, and variation of superficial temperature according to solar influence, we are at liberty to suppose the existence of deep seated heat of any intensity, provided there be direct indications of corresponding augmentation of sensible temperature below a certain depth. Such indications, it is very generally allowed, are presented by the observations in mines and collieries in Europe, Asia, and America.

Secular refrigeration.

With regard to secular refrigeration, the experience of two thousand years undoubtedly shews that its effect in contracting the Earth's diameter has been for that period insensible; but, first, it must be observed, that the hypothesis supposes the effect of refrigeration to be a contraction of an internal nucleus, and a consequent separation between it and the solid crust, which continually increases until the crust is broken by a *convulsive collapse;* secondly, it is sufficiently evident that, by the accumulation of nonconducting materials over a source of heat, the diminution of this heat must become continually more and more slow, so as at last to be insensible even in very long periods. If, then, it should appear that the leading phenomena of the ancient History of the Earth can be well explained by help of these suppositions, there is nothing in the mathematical theory to prevent their provisional adoption, on the basis, not unfrequently employed in Natural Philosophy, that they serve to explain many phenomena.

Volcanic action.

It is by no means necessary to couple with the hypothesis of internal heat, the doctrine that volcanic action arises from this cause only: the various chemical characteristics of volcanic action must be examined upon their own evidence; and it does not appear that the theory of volcanic operations, advocated in a former part of the Essay, is at all deprived of its applicability, or rendered superfluous, by admitting the existence of intense internal heat. On the contrary, under the influence of a high temperature, the admission of oxygen and water would still produce upon the fluid metalloids and metals the effects usually ascribed to such a cause, and perhaps more easily than if they were solid, and the results would still be proportioned to the circumstances of the locality.

These remarks are not introduced for the purpose of advocating the hypothesis in question, but to rescue those who have adopted it, and by it endeavoured to illuminate some of the darkest pages of Geology, from the imputation of invoking causes which chemical and mathematical researches concurred in disproving.

Displacement of the Earth's axis.

The moderation which Geologists were so slow to learn, has prevented them from reviving the ancient speculation which ascribed the leading phenomena of Geology to an extensive shifting of the Earth's axis, and consequent displacement of the Ocean. To be consistent, we must suppose this mighty operation to have been many times repeated before the occurrence of the Deluge which it was invented to explain. Perhaps the *probability* that every part of the Globe *equally* requires this displacement of the axis, but requires it in *different directions at the same time,* may be sufficient to

prevent its resuscitation. It is too much, however, to treat it as an absurdity, merely upon the ground that the shells of equal density within the Globe have their axes, at the present moment, nearly coincident with those of the surface; for Sir J. Herschel has expressed the opinion that the spheroidal figure of the Earth might be acquired during rotation though its parts were not fluid.

But, as Mr. Greenough has observed, "be the cause what it may, the fact is certain, that the temperature of the crust of the Earth was higher when the coal measures were deposited than now, and we have reason to think it was still higher at antecedent periods. That a considerable degree of heat still exists, either partially or generally, at no great distance from the surface, appears from thermal springs and volcanoes." (*Geological Society's Proceedings*, 1834.)

Origin of terrestrial organic life. In accordance with this view is the common opinion, that geological inquiries have discovered traces of a period in the History of the Globe, when neither animal nor vegetable life was established upon it. This opinion, ably expressed by Dr. Buckland in his *Vindiciæ Geologicæ*, is chiefly supported by the facts observed in studying the primary and transition strata. The view of the subject which is most consonant to the course of inferences adopted in this Treatise, has been already sufficiently expressed in the review of the primary strata, (p. 570, 571.)

Whatever may be truth on this point, it is certain that the successive systems of organic life, both terrestrial and aquatic, animal and vegetable, show the same general principles and relations as that to which we belong. Geology has disclosed various and remarkable animals, not paralleled in existing nature, and plants of singular forms, but nothing which deviates from those general laws of structure and function which govern the actual organic creation. The plants and animals of different geological periods do not differ more from one another, than those in opposite climates, or even distant localities at present. There is even to be observed among the several successive systems of organic remains some real analogy to existing local Faunas and Floras: the oolitic fossils have, perhaps, a greater resemblance, for instance, to the living productions of Australia and the Indian Islands, than to those of any other situation; while the plants and uniones of the Northern English coal tracts remind us of the physical characters of the American continent rivers and islands.

Periods of convulsion and repose. There is, perhaps, no point of theoretical Geology more certainly established than that, in any given small area of the surface of the Globe, long periods of ordinary action of natural causes have been several times interrupted by epochs of extraordinary disturbance; that the relation of the level of sea and land has remained for a long time the same, or very gradually changed, and afterwards been altered by internal convulsions. It is also admitted that this law has an extensive though then less exact application; that the periods of ordinary and crises of extraordinary action were respectively contemporaneous over very large regions of the Globe, and even with respect to some of the cases admit of general application. It appears, also, that the nature of the strata deposited differs more or less according to the several successive periods, and that the races of organic remains, in several important cases, are subject to contemporaneous crises. On this evidence, joined to some theoretical considerations, is founded the modern admission of the doctrine of alternating periods of convulsion and repose; a doctrine which was held by ancient Philosophers, revived by Leibnitz and Hutton, and illustrated by Cuvier and De Beaumont. Perhaps this view of the subject was never more clearly expressed than by Leibnitz, whose just sense of the philosophy of Geology has been lately placed in a strong light by Mr. Conybeare. His view is, that the powerful agencies exerted in displacing and altering the solid crust which gradually thickened over the ignited nucleus, have many times renewed the face of the young Globe by the eruption of concreted igneous rocks from below, and the deposition of stratified rocks by water above; and that the Globe was, by these processes, more and more diversified with mountains and valleys, and subjected to various physical conditions; *donec quiescentibus causis, atque æquilibratis, consistentior emergeret rerum status.*

Uniformity of natural agencies. Mr. Lyell's pictures of the successive conditions of the Globe are all drawn to one scale, from the unvarying standard of its present state; his hypothesis admits local alternations of ordinary and critical action, but denies any thing like a general paroxysmal effort of natural agents; nor is there, between the ordinary and critical stages of his processes, any conspicuous difference. The principle of his system is, that the disturbing internal forces exert themselves in irregular succession beneath all the points of the surface of the Gobe; and that the ordinary chemical and mechanical agencies of Nature are thus modified in their intensity, and diversified in their effects, and applied to produce an endless series of destructions and renovations, which, upon the whole, compensate one another continually.

In this system, the postulate required is *unlimited duration;* in the other, a varying momentum of natural agencies according to *difference of condition:* the one is a system of continual, the other of intermittent compensation. Nature offers to our view examples of both these cases, and on a large scale; it is therefore very unwise to assume one or the other on account of our notion of its greater probability; we must see which of the systems finds support from the facts of the case. It has been already seen that our *proofs* of the periods of time elapsed are neither clear, satisfactory, nor complete; much of the evidence on this subject is in unknown terms; but estimates derived from probable views of the mechanical composition and organic contents of the strata, do not appear to warrant the postulate of unlimited duration. (See p. 795, 796.)

On the contrary, be the duration of geological periods what they may, it is clear that the Earth has successively undergone great physical changes; terrestrial agencies must therefore have operated upon it with a corresponding variation of effect; one of these changes of condition, that of superficial temperature, is not explicable by any of the known periodical inequalities of the Solar system, but seems in harmony with the general theory of internal heat, gradually becoming less and less sensible as the external crust thickened, and the surface of the Globe approached to a state of equilibrium.

Successive Conditions of the Materials of the Crust of the Globe.

The question of the origin or first condition of the elementary ingredients of earthy and metallic substances, if capable of solution, must be referred to another Science; but inquiries into the successive conditions of

the mineral substances which appear in the crust of the Globe, is one which, in some shape or other, must be often proposed to a Geologist. It is difficult to stop at the recognition of the igneous origin of some rocks, the aqueous production of others; we cannot avoid examining, whether any evidence can be found for determining a prior condition of the substances contained in these rocks. Facts of great importance here come before us; we see examples of new rocks produced by heat from aqueous deposits, and sedimentary aggregates of the disintegrated ingredients of volcanic and plutonic masses. The deposition of limestone offers very remarkable variations, and it is impossible to consider the composition of the minerals in crystallized rocks, without feeling that the resources of Chemistry are or may become capable of advancing us one more step in the analysis of the series of conditions through which the solid ingredients of the Globe have passed.

The time is not long gone by when Werner, who, with far less moderation than Dr. Hutton, wished to begin at the beginning, could find thousands of followers in the startling dogma, that all the rocks observed near the surface of the Earth, were deposited from one chaotic fluid, which first permitted the crystallization of granitic and other rocks, and afterwards produced the secondary sandstones, shales, and limestones. It is possible that even yet there may be persons who can believe that these secondary sandstones were produced by a chemical decomposition of the ancient Ocean; which, to answer all the unreasonable demands upon its powers, must have been endowed with more than the creative energy of a Brahmà, and capable of surmounting every chemical and mechanical impossibility—of crystallizing into sand, condensing into limestone, and subliming into metal!

Leibnitz, and a large portion of modern Geologists, also attempt to fix something like a beginning to their system, a point of geological time when the change from a fluid to a solidified surface permitted the developement of that series of intermitting igneous and aqueous actions, which has brought the Globe by many revolutions to its present state of comparative repose. The followers of Dr. Hutton see no such commencement to their series of terraqueous effects; they find no physical traces of a beginning, nor any change of operation which should give the prospect of an end of this series of effects proportioned to the time elapsed. Yet, as one hypothesis admits locally, periodically, and repeatedly, what the other supposes to have happened generally and in one succession, there is no necessary disagreement in the interpretation of particular cases. This is not always remembered by those who engage in the controversy concerning the uniformity of natural effects.

Successive conditions of certain substances.

If we trace back the history of the materials of the sedimentary sands and clays now in process of formation at the mouths of rivers, along the sea-coasts, and in other situations, we shall find that these materials are often derived from ancient superficial deposits left by local or extensive floods; examination proves that the materials of these deposits were often obtained by the violent breaking up and attrition of far more ancient previously solidified strata; in several instances it is manifest that these are nothing else than the oceanic accumulations derived from disintegrated primary strata, or of disintegrated pyrogenous rocks.

As an example, we shall quote a well-ascertained series of facts, which leave no doubt of the many changes of condition through which the granular ingredients of modern sedimentary deposits have passed. 1. The Ouse, Trent, and other great rivers connected with the Humber, are so filled with the finer parts of the sediments which fall into the sea along the wasting cliffs of Holderness, that their flood-waters, when introduced to the lower ground along their banks, deposit a great thickness of valuable soil. The sandy and coarser parts of the sediment are collected in various irregular positions in the Humber and along the coast, and the pebbles remain on the beach, or follow its descent for a small distance into the sea. 2. The diluvial cliffs, which by their destruction afford this rich supply of fertile warp and sterile sand, contain fragments of all the rocks in North-Western Yorkshire, that is to say, basalt, limestone of many kinds, cherts, sandstones, fine-grained and coarse-grained millstone grit, shales, ironstones, and coal; fragments of granite, hypersthene rock, and greywacke slates from Cumbria; all imbedded in a vast thickness of sands and clays composed of the same comminuted materials. 3. The millstone grit, fragments of which occur in this diluvial mass, is a compound of felspar, quartz, and mica, with occasional admixtures of other substances. These minerals are easily recognised as *rolled and water-worn masses*, derived from porphyritic granite, gneiss, and other such rocks. The felspar is always perfectly crystallized within, but the external surface is water-worn; the mica has lost its angles; and the quartz fragments are only in the state of large grained sand. Plainer proof of mechanical aggregation of ingredients which once composed a crystalline felspathic rock, cannot be desired; many such instances are known, and the inference is generally allowed.

Extension of this inference.

As far as the results of a careful examination of ordinary sandstones can be trusted, there is no reason to refuse to them, as a general rule, the same kind of origin as to coarse millstone grit. Most of them have the same ingredients, though it frequently happens that the felspar is in a state of decomposition. Shales and clays are to sandstones what the fine warp in the water of the Humber is to the sands in its channel; we may then venture, in a moderate spirit of generalization, to assume, that sedimentary sandstones and shales have originated in the mechanical action of water upon the disintegrated granular ingredients of pyrogenous rocks.

Any one who has sufficiently observed the varieties of sandstones and shales on the one hand, and of stratified primary rocks on the other, and considered the nature and amount of the changes produced upon them respectively by heat; or properly weighed the observations and reasonings of Macculloch; will have no difficulty in admitting the views as to the origin of the latter class of strata advocated in former parts of this Essay. We are therefore conducted, apparently by a legitimate process of induction, to the conclusion that all the stratified rocks, limestone and some particular strata excepted, are derived primarily from the decomposing agencies of Nature operating upon pyrogenous rocks; and we thus find a natural limit to the series of conditions through which these materials have passed. This conclusion, though perhaps less distinctly stated, is essentially recognised in modern geological systems and is *felt* to be substantially true, though it still leaves many things to be explained.

An inquiry as to the origin of the vast masses of stratified limestone, is a subject of considerable difficulty. In a great majority of instances the limestone

formed at the present day is the result of chemical forces, and the same was probably the case in earlier periods. In particular instances, calcareous deposits have partially or wholly a mechanical origin; as when a stream brings down the waste of a chalky or oolitic district, and deposits the sediment in a lake; or when the currents of the Ocean drift shells and other marine exuviæ and lodge them in the midst of coral reefs. Observers of the growth of coral islands have detected several facts as to the intermixture of decomposed fragmentary and entire calcareous marine exuviæ with coral rock, which seem to render not improbable the opinion of Geologists, that some of the older secondary and transition limestones are in places only magnificent coral reefs.

Origin of limestone.

Perhaps nowhere has the mechanical origin of limestone been assumed to a greater extent than in the Huttonian system of Geology; for it seems to be an essential part of that system, that the stratified limestones are nothing else than triturated shells and other calcareous exuviæ. By those who adopt this view, chalk, the least compacted kind of limestone, is usually taken as an example. It is sometimes difficult to avoid imagining that the powdery magnesian limestone is a recomposed rock, derived from the ruins of magnesian beds of carboniferous limestone. But this cannot be a true account of the matter; for, 1. there ought to be far *less magnesia* in the compound. 2. This is in some instances an atomic combination of carbonate of magnesia and carbonate of lime. 3. This limestone is often really a granularly crystalline rock, (like the older magnesiferous beds of mountain limestone,) and seldom appears to justify the least suspicion of the mechanical agency of water.

But nothing is more certain than that of all the strata yet discovered, limestone is exactly that which, by the regularity and continuity of its beds, by the extreme perfection of its organic contents, and by the absence of proofs of mechanical action, gives most completely the notion of a chemical precipitate. It appears sufficiently probable, in several instances, that the quantity of limestone deposited in a given geological period was least towards the shores, and greatest towards the deep sea; exactly the reverse of what happens with the mechanical deposits of sandstone and shale; it may therefore be viewed as an oceanic deposit, resulting from a decomposition of sea water, aided in many instances to a wonderful extent by the vital products of zoophytic, echinodermatous, and molluscous animals. According to this view, it is easy to understand the repeated production of limestones of the same mineral character at different periods; nor need we feel surprised that, occasionally, limestones of the same age differ in properties.

However, all these views end at last in one, *viz.* that the earliest condition which we can assign to the carbonate of lime, is that of extrication from some solution of lime in water, by chemical or vital processes. And here, perhaps, it will be wisdom to pause, for though some have ventured to imagine that the lime might be derived from the decomposition of particular ingredients in primary igneous rocks, and others may suppose that the Ocean would more directly obtain this with other ingredients from the oxidized fluid nucleus of the Globe, such speculations are beyond the pale of Inductive Geology, and involve too many hazardous assumptions to be at present worthy of the notice of other Sciences.

General result.

The general tendency of geological reasoning is to establish the inference, that a large portion of the stratified deposits have been formed from the wasted ingredients of pyrogenous rocks: all the phenomena of volcanoes and ancient igneous eruptions prove that *locally* stratified deposits are reconvertible to crystalline rocks by the force of heat, and very *generally* alterable in character so as to approximate to the actual products of heat. Mr. Lyell puts this to the extreme, and supposes that the calorific energy of the interior of the Earth is constantly acting, so as to reconvert sedimentary into crystalline aggregates, *equal quantities* in *equal times*, and thus to maintain a perpetual equilibrium between the liquefying internal and the solidifying external agencies of the Globe. This speculation is much too poetical to be examined according to the dry rules of the Baconian Philosophy: if the heat expended in this operation be obtained from chemical processes, these must gradually tend towards equilibrium; if from a general internal reservoir of caloric, that reservoir must become less and less prompt in supplying the incessant demand: either of these effects operating through *indefinite time* must cause the gradual refrigeration of the surface of the Globe, a consequence not favourable to the hypothesis of the uniformity and continual compensation of the effects of internal and external terrestrial agencies.

Reference to Plates II. and III. of Organic Remains.

Plate 2.

Tertiary System.

1. Voluta dubia. *Brander.*
2. Dentalium striatum. *Sow.*
3. Venericardia planicosta. *Sow.*
4. Fusus bulbiformis *Sow.*
5. Emarginula reticulata. *Sow.*
6. Cytherea lentiformis. *Sow.*
7. Turbo littoreus. *Sow*
8. Scalaria foliacea *Sow.*
9. Murex tubifer. *Sow.*
10. Fusus contrarius. *Sow*
11. Cypræa Avellana. *Sow.*
12. Trochus agglutinans. *Brand.*
12.* Pleurotoma exorta, *Sow.*

Cretaceous System.

13. Pecten quinquecostatus. *Sow.*
14. Apiocrinus ellipticus *Mill.*
15. Spongia cribrosa. *Phil.*
16. Marsupites Millerl. *Mantell.*
17. Inoceramus sulcatus *Sow*
18. Trigonia aliformis *Sow.*
19. Catillus Brongniarti. *Sow* and *Brong.*
20. Ammonites varians. *Sow.*
21. Plagiostoma spinosum. *Sow*
22. Belemnites mucronatus. *Cuv.* and *Brong.*
23. Spatangus Cor-anguinum. *Cuv.* and *Brong.*
24. Scaphites costatus. *Mantell.*

Oolitic System

25 Trigonia costata. *Sow.*
26. Vertebra of Plesiosaurus.
27. Cidaris intermedia. *Fleming.*
28. Clypeus clunicularis. *Lhuyd.*
29. Vertebra of Ichthyosaurus communis, *Conyb.*
30. Ammonites Walcottii. *Sow.*
31. Pholadomya Murchisoni. *Sow.*
32. End of the Upper Jaw of Crocodile.
33. Mya V. scripta. *Sow.*
34 Gryphæa incurva. *Sow.*
35. Ammonites Calloviensis. *Sow.*

Plate 3.

Saliferous System.

1. Producta horrida. *Sow.*
2. Retepora virgulacea. *Phil.*
3. Terebratula globulina, *Phil. MS.*
4. Terebratula.
5. Pecten radialis, *Phil MS.*
6. *a* Avicula gryphæoides. *Sedg.*
   b. Dorsal view of the same.
7. Axinus obscurus. *Sow.*
8. Retepora flustracea. *Phil.*
9. Palæothrissum macrocephalum. *Sedg.*

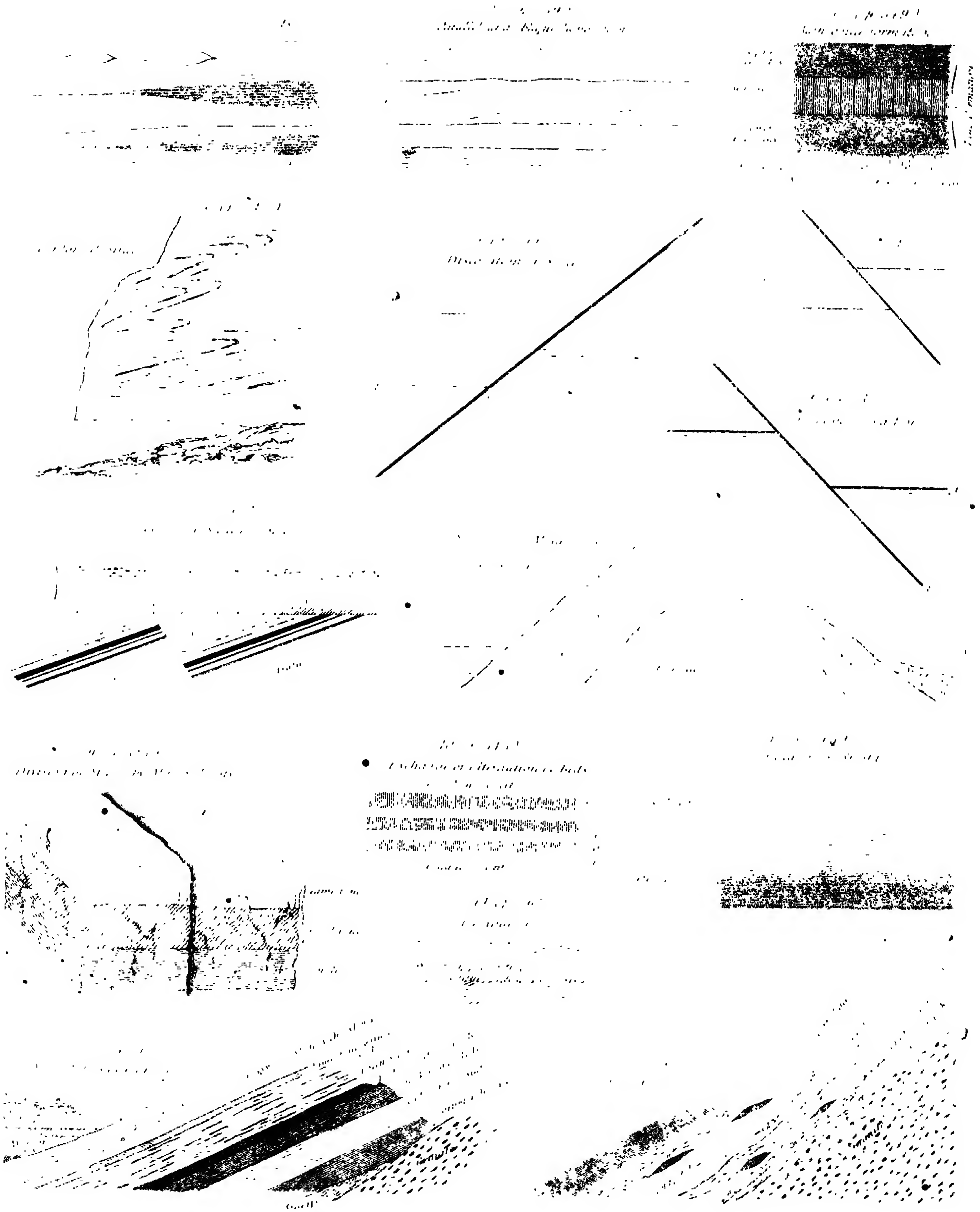
Carboniferous System.

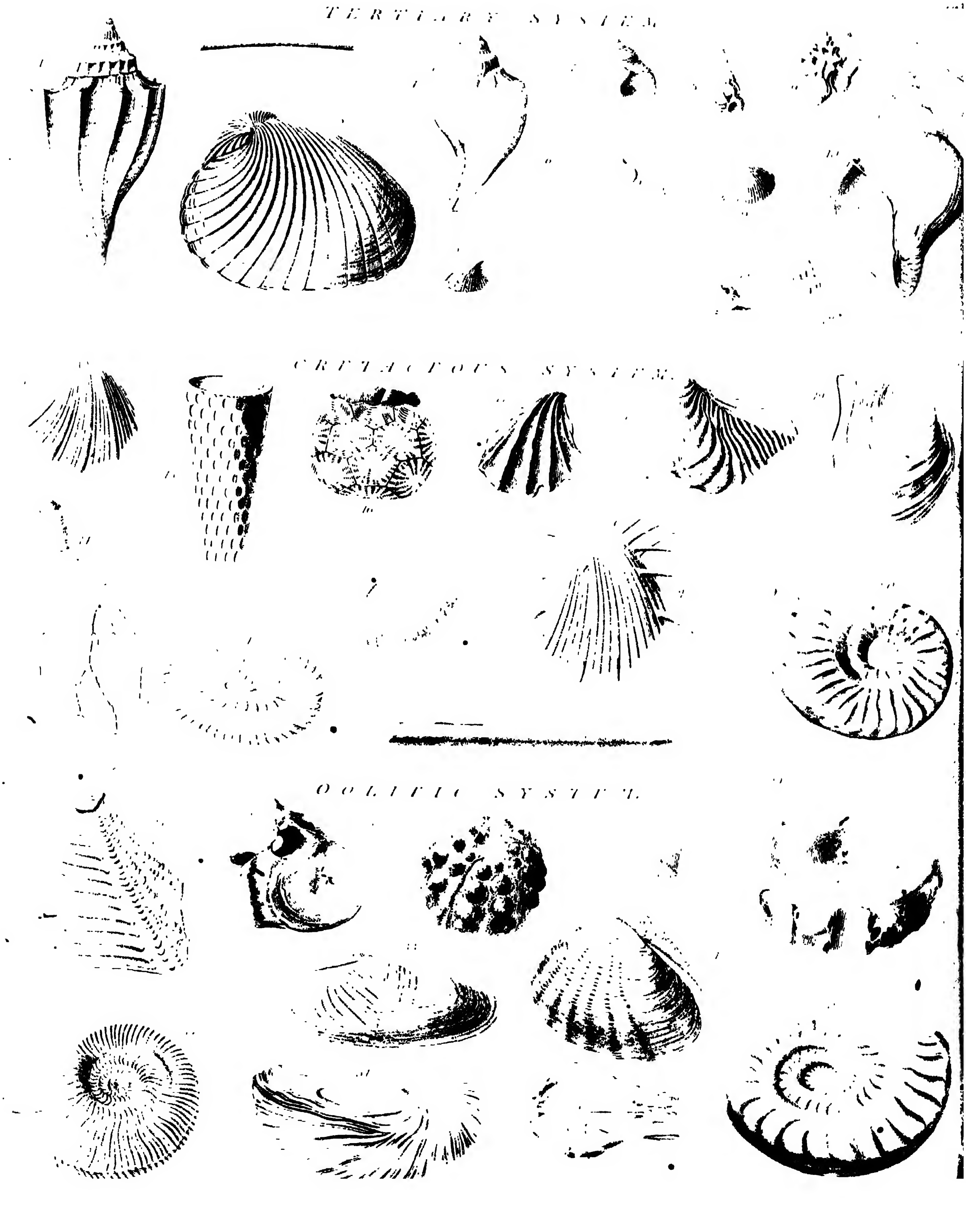
10. Platycrinus lævis. *Mill.*
11. Actinocrinus 30 dactylus. *Mill.*
12. Pentremites ellipticus. *Sow.*
13. Pleurorhynchus minax. *Phil. MS.* (New genus)
14 Orthoceras Breynii. *Sow.*
15. Spirifera striata. *Sow.*
16. Producta punctata. *Sow.*
17. Ammonites Listeri. *Sow.*
18. Ammonites striatus. *Sow.*
19. Bellerophon hiulcus, *Sow.*
20. Pleurotomaria, (Helix carinata? *Sow.*) colour stripes remaining.
21. Euomphalus pentangulatus. *Sow*
22 Syringopora geniculata. *Phil MS.*
23. Favosites capillaris, *Phil. MS.*
24. Asaphus gemmuliferus. *Phil. MS. magnified twice.*
25. Terebratula acuminata. *Sow.*

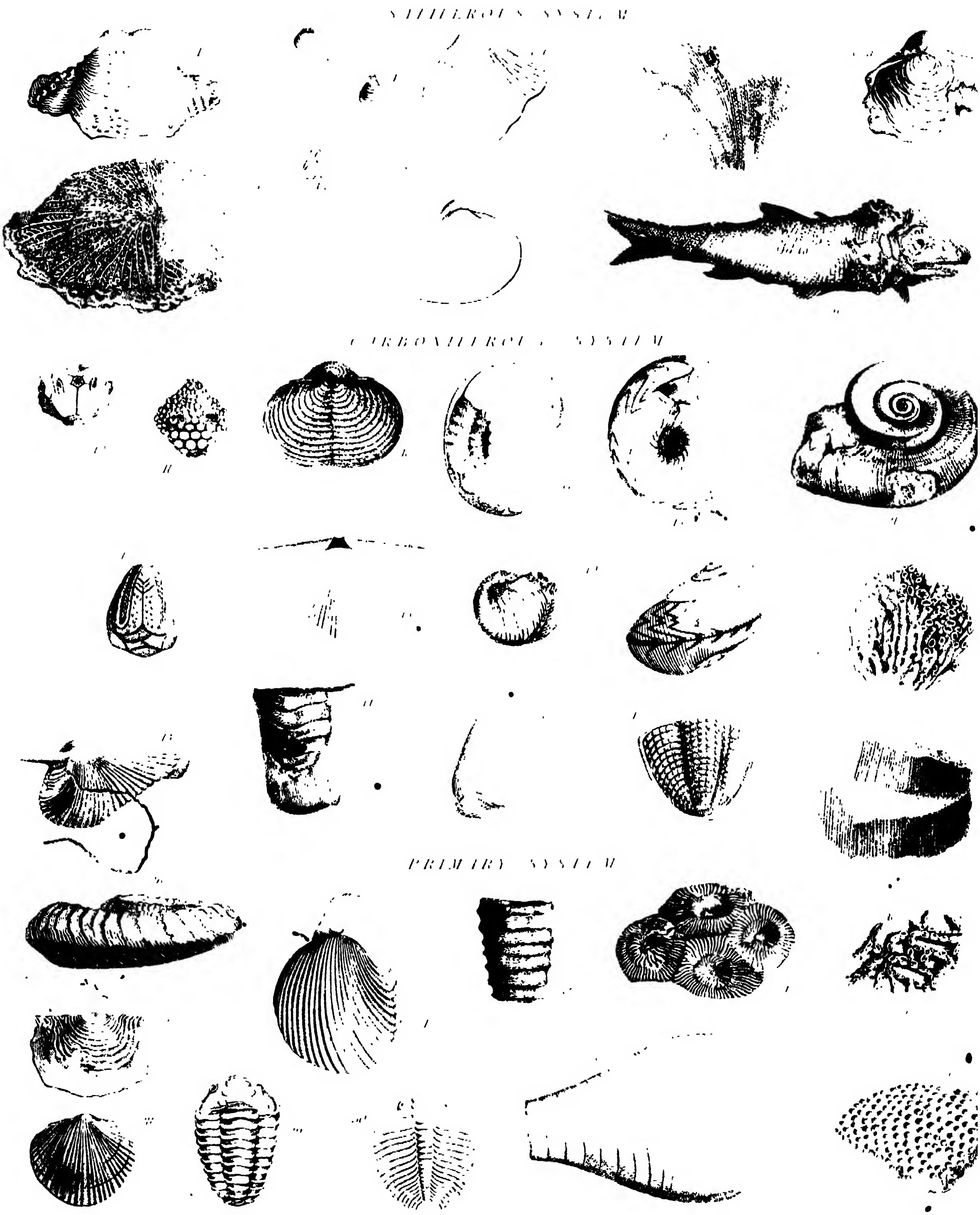
Primary System.

26. Euomphalus discors. *Sow.*
27. Producta depressa. *Sow.*
    Dorsal view of the lower valve.
28. Terebratula affinis. *Sow.*
29. Calymene Blumenbachii. *Brong.*
30. Asaphus De Buchii. *Brong.*
31. Pentamerus Knightii. *Sow.*
32. Orthoceras annulatum. *Sow.*
33. Orthoceras pyriforme. *Sow.*
34. Cyathophyllum hexagonum. *Goldfuss.*
35. Catenipora labyrinthica. *Goldf.*
36. Astræa porosa. *Goldf.*

GEOLOGY.

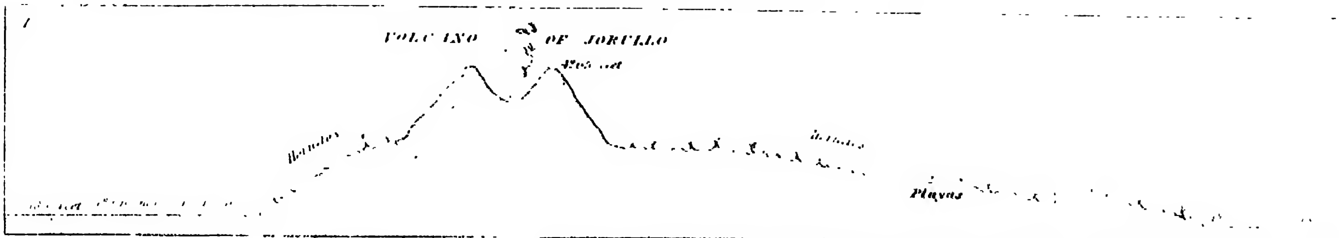



TERTIARY SYSTEM
CRETACEOUS SYSTEM
OOLITIC SYSTEM


CARBONIFEROUS SYSTEM
PRIMARY SYSTEM

GEOLOGY.

Volcanos

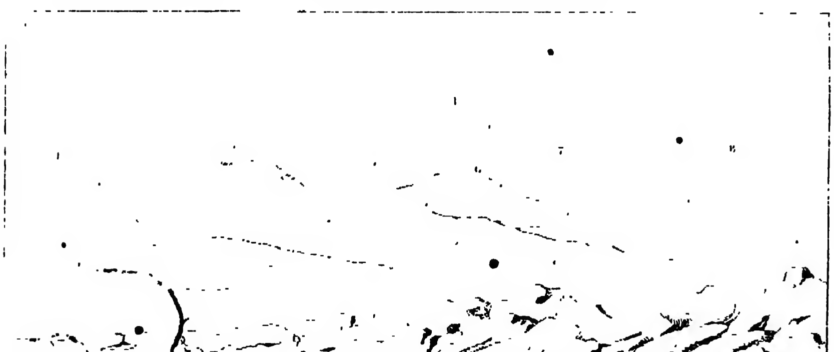


Section of Jorullo and the Malpais

View of the Volcano of Jorullo, Mexico

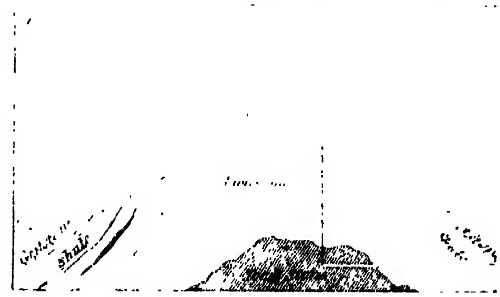
Crater in Lanzarote Island of Canaria

Cone & Crater in Barren Island Bay of Bengal

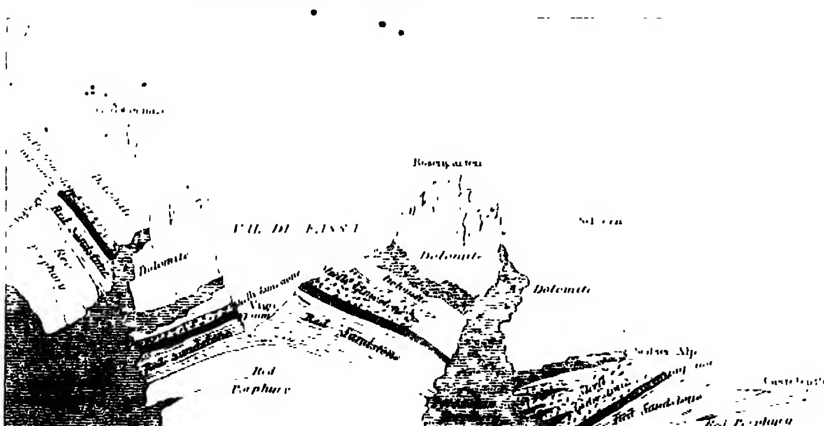


Volcanic Hills near Clermont in Auvergne seen from the Puy Chopine

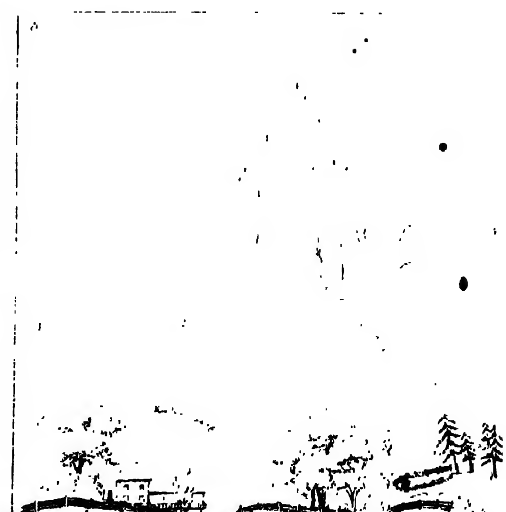
1 Grand Sarcoui 4 Puy de Dome 7 Grand Suchet
2 Puy Pariou 5 Petit Suchet 8 Puy de Come
3 Petit Puy de Dome 6 Clierzou



Section of Crich Hill near Matlock

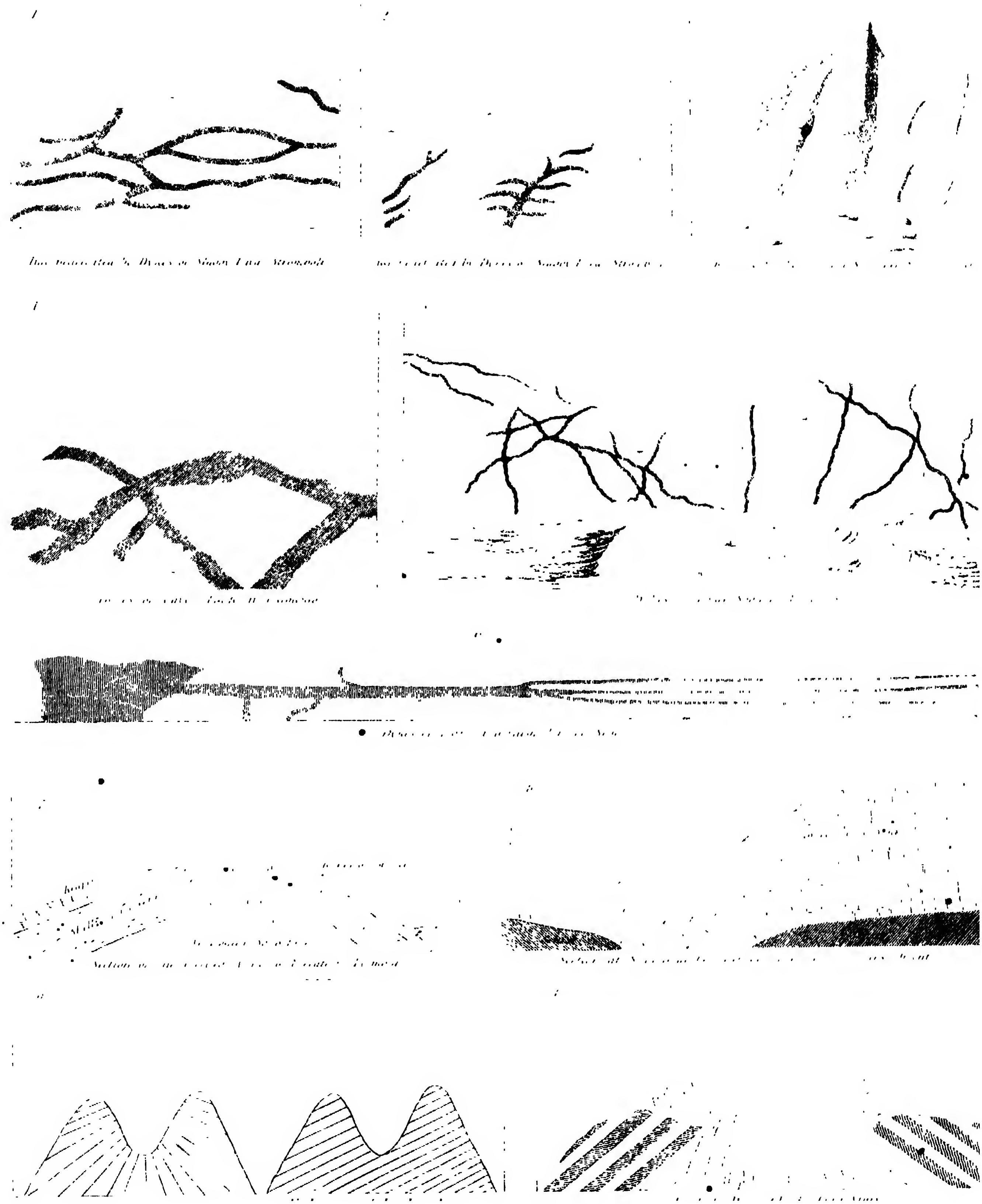


Section of the Mountains in the Val di Fassa



Landslip of a Mountain of Dolomite in the Valley of ... Tyrol

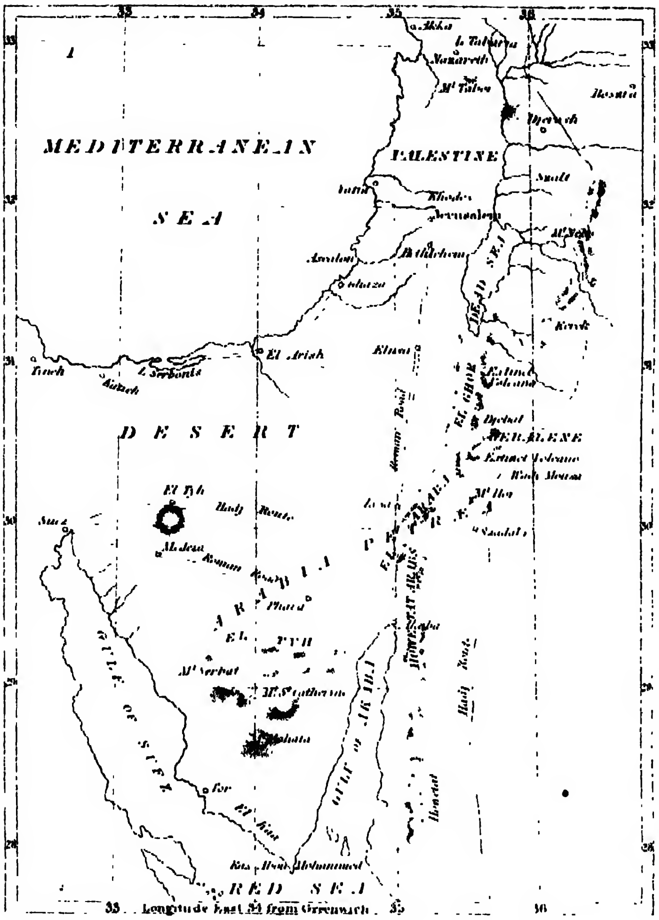
GEOLOGY.



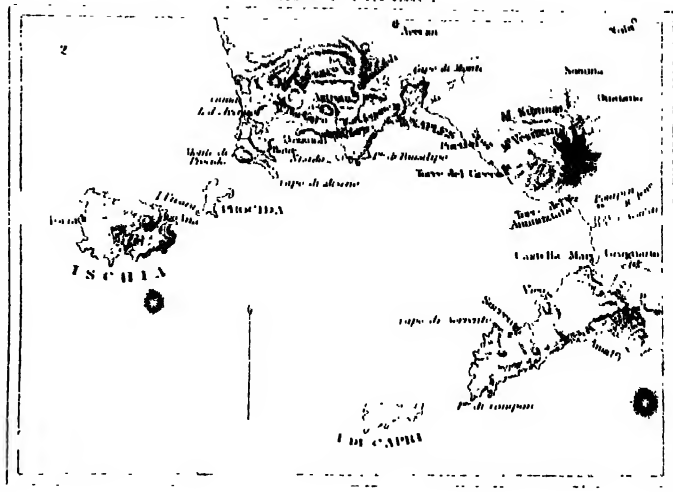
GEOLOGY.

Volcanos

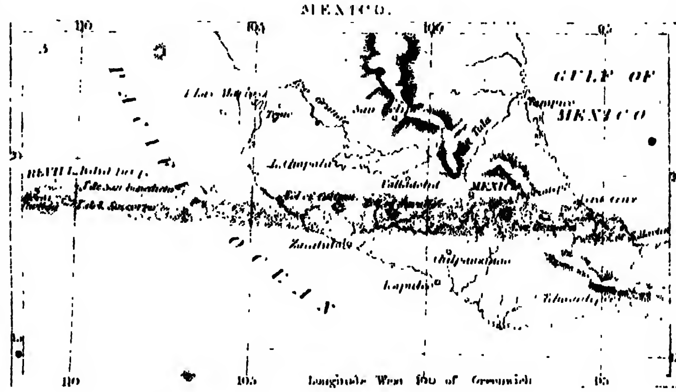
PALESTINE AND THE DEAD SEA.



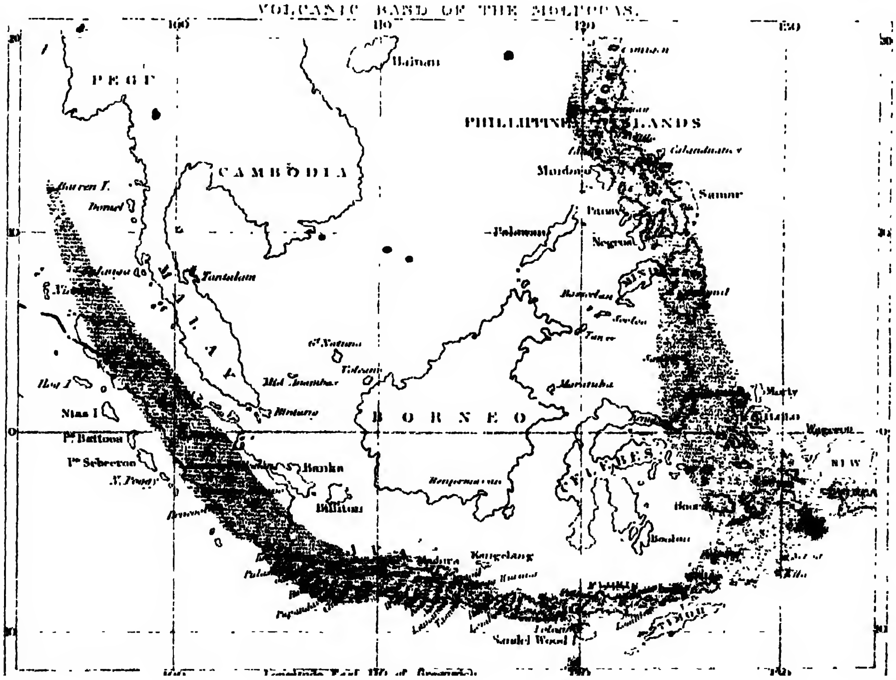
BAY OF NAPLES.



MEXICO.



VOLCANIC BAND OF THE MOLUCCAS.



VOLCANIC BAND OF THE GREEK ISLANDS.

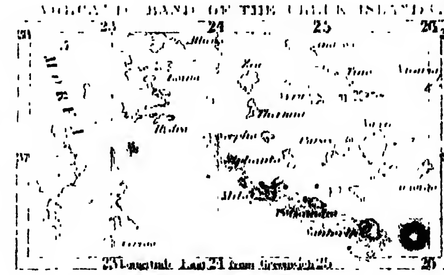
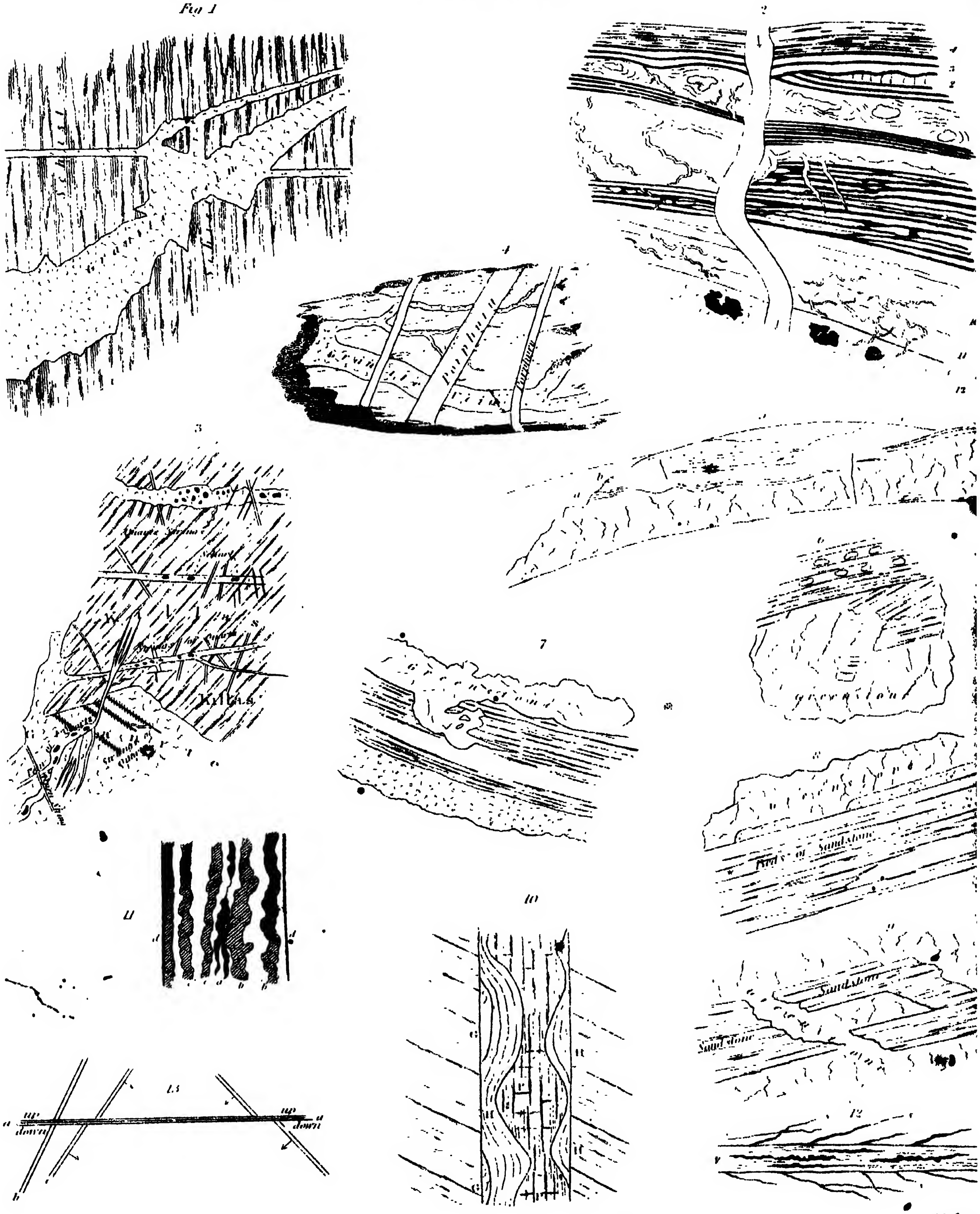


CHART & SECTION OF SANTORINO &c.



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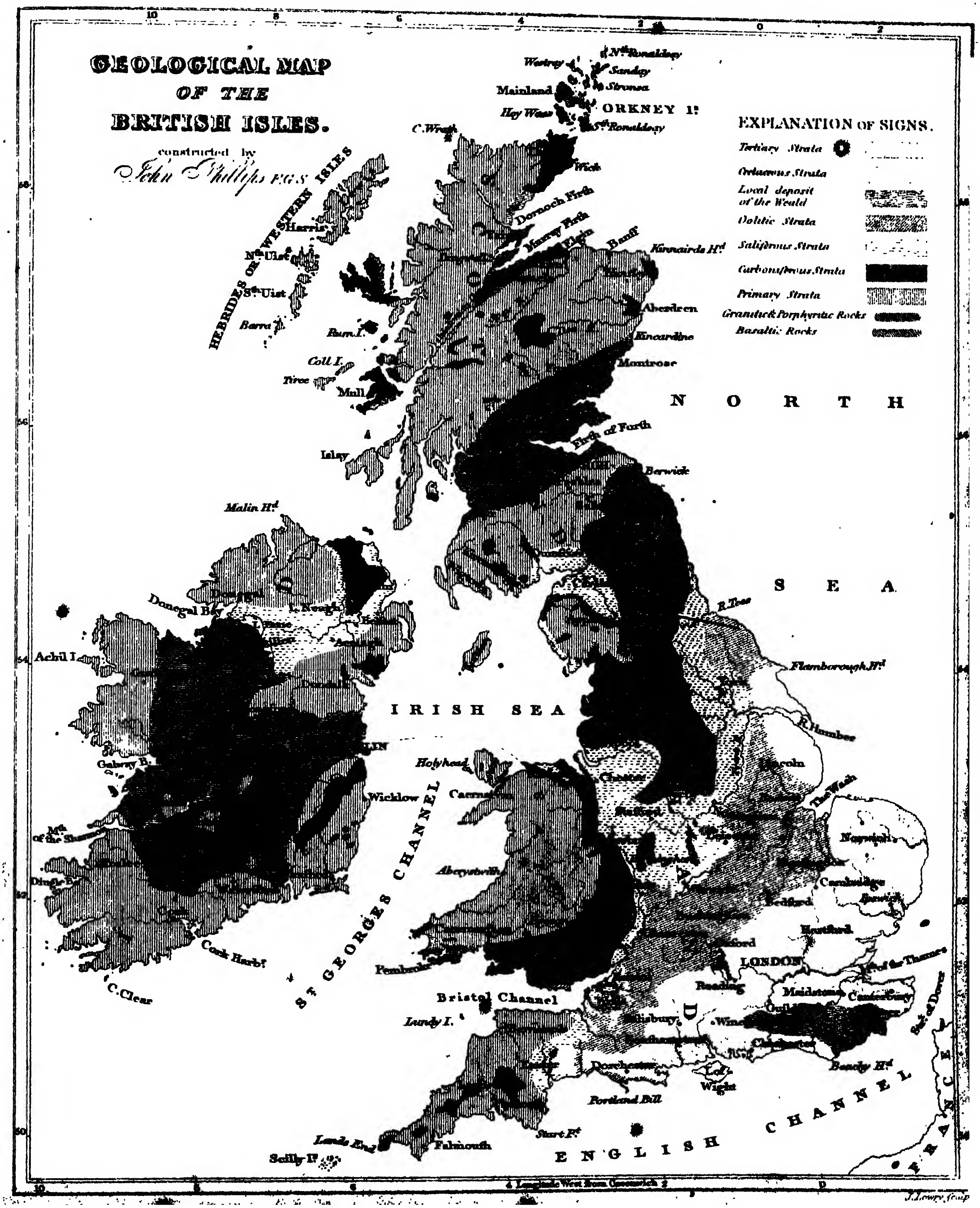
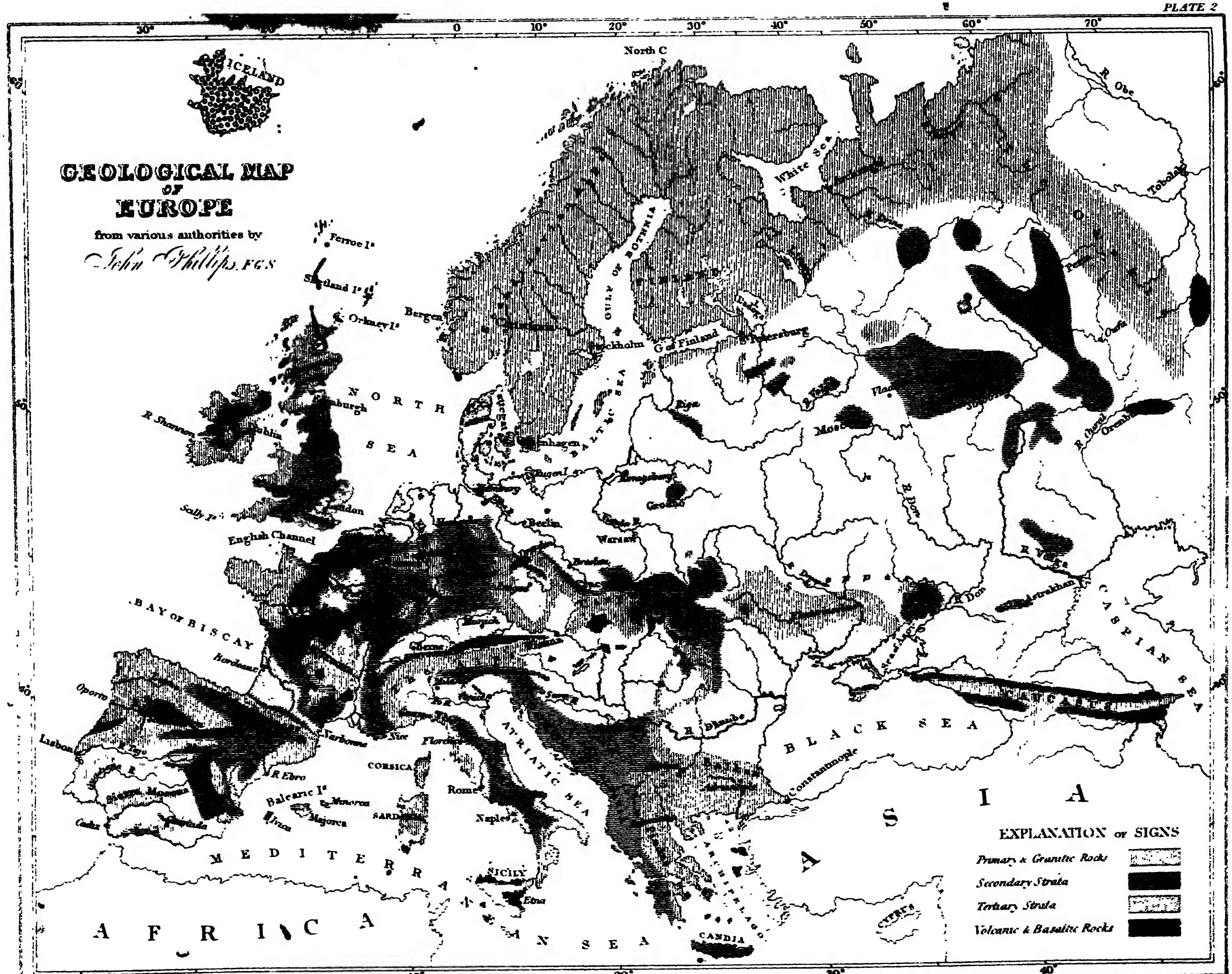

GEOLOGICAL MAP
OF THE
BRITISH ISLES.
constructed by
John Phillips F.G.S.
EXPLANATION OF SIGNS.
Tertiary Strata
Cretaceous Strata
Local deposit of the Weald
Oolitic Strata
Saliferous Strata
Carboniferous Strata
Primary Strata
Granitic & Porphyritic Rocks
Basaltic Rocks
ORKNEY Is
Westray
Nth Ronaldsay
Sanday
Stronsa
Mainland
Hoy Water
Sth Ronaldsay
C. Wrath
Wick
Dornoch Firth
Murray Firth
Elgin
Banff
Kinnairds Hd
Aberdeen
Kincardine
Montrose
HEBRIDES OR WESTERN ISLES
Harris
Nth Uist
Sth Uist
Barra
Rum I.
Coll I.
Tiree
Mull
Islay
Firth of Forth
Berwick
NORTH
SEA
Malin Hd
Donegal Bay
L. Neagh
Achil I.
Galway B.
Mth of the Shannon
Dingle B.
Cork Harbr
C. Clear
Wicklow
IRISH SEA
R. Tees
Flamborough Hd
R. Humber
Lincoln
Holyhead
Chester
The Wash
Norwich
Cambridge
Bedford
Hertford
LONDON
Mth of the Thames
Maidstone
Canterbury
Aberystwith
ST GEORGES CHANNEL
Pembroke
Bristol Channel
Lundy I.
Reading
Chichester
Beachy Hd
Dorchester
Portland Bill
I. of Wight
Start Pt
Lands End
Falmouth
Scilly Is
ENGLISH CHANNEL
FRANCE
Longitude West from Greenwich
J. Lowry sculp


GEOLOGICAL MAP
OF
EUROPE
from various authorities by
John Phillips, F.G.S.
EXPLANATION OF SIGNS
Primary & Granitic Rocks
Secondary Strata
Tertiary Strata
Volcanic & Basaltic Rocks
ICELAND
North C
Ferroe Is
Shetland Is
Orkney Is
Bergen
NORTH SEA
R Shannon
Dublin
English Channel
BAY OF BISCAY
Bordeaux
Oporto
Lisbon
R Tago
R Ebro
Balearic Is
Minorca
Majorca
Iviza
Cadiz
Narbonne
Nice
Florence
CORSICA
Rome
Naples
SICILY
Etna
MEDITERRANEAN SEA
AFRICA
ADRIATIC SEA
ARCHIPELAGO
CANDIA
CYPRUS
BLACK SEA
Constantinople
R Danube
CASPIAN SEA
ASIA
GULF OF BOTHNIA
White Sea
Stockholm
G of Finland
St Petersburg
Ladoga
BALTIC SEA
Copenhagen
Berlin
Warsaw
Riga
Grodno
Moscow
R Don
R Volga
Astrakhan
Orenburg
Tobolsk
R Obe
30°
0
10°
20°
40°
50°
60°
70°

INDEX TO GEOLOGY.

To facilitate the study of the Article Geology, and to make known the nature and the views advanced in it, is the object of the following abstract. The subjects discussed in Geological Treatises of modern date are, of necessity, extremely varied, for the Natural History of the Earth is too vast and diversified a problem not to require continual reference to the truths of collateral Science. In the present Treatise, a great portion of the inferences and general reasoning is, indeed, collected into a separate and final chapter; yet, in many instances, the inferences from phenomena are introduced after the description of these, especially when it seemed likely to render the succeeding descriptions more clear. The following summary will explain the distribution of subjects throughout the four Chapters of the Treatise, and serve as a General Index, permitting, at the same time, a connected view of the Science.

CHAPTER I.

PROGRESS AND PRINCIPLES OF THE SCIENCE.

Progress of the Science.

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529 *Definition*, with reasons for its wide limits.
Speculative Geology gradually changing, with the progress of Physical Science, into

530 *Inductive Geology*, which, in different Countries, was based on different data. *Lister* originated the *agricultural school of Geology*, which has nowhere made progress commensurate with its importance.
Mining knowledge was the basis of another school brought to eminence in Germany under the auspices of Werner, who claims the merit of introducing, more clearly than had been done before, the consideration of relative time and succession of phenomena.—Of this

531 *Werner's series of formations* is a remarkable monument.
Mitchell, *Whitehurst*, and *Saussure* have distinct claims to praise, the former for comprehensive views, the latter for diligent researches.

532 *Inductive Geology* was, however, principally founded on a *knowledge of organic remains*. Rude admiration of these monuments of earlier Nature animated, nearly at the same time, the Naturalists of Italy, France, and England; and the discussions respecting their origin led to the introduction of Zoology and Botany as auxiliary Sciences to Geology: and in Mr. Smith's hands to

533 *A correct classification* of stratified rocks, and the important discovery of the relation of *systems of organic life* to definite geological periods.

534 *Hypotheses* are thus devoted to oblivion, and *the modern cultivators of Geology*, aware of the grand problem committed to their industry, labour assiduously, and labour together, in the patient interpretation of Nature.

Materials in the Earth.

The mean density of the Earth, as known by astronomical and mechanical discoveries, combined with other knowledge, leads to three probable deductions as to the *interior* of the Planet, which are stated, and which are of great importance in limiting the range of geological speculation.

535 *The earthy compounds of the exterior* of our Planet, as known by observation, are referred to certain groups according to their chemical constitution.

Stratification.

536 *The regular arrangement of rocks on the surface* is shown to depend on a *regular internal arrangement* called stratification; such that the "strata are arranged, with respect to one

537 another, in a constant order of succession." From this *superposition of strata*, with according *declinations*, and considerable extent or *continuity*, it follows, that *stratification* is a fundamental condition of many rocks, and that the Earth is externally of a lamellar structure, the layers marking particular periods of its formation.

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Distinction of Stratified and Unstratified Rocks.

537 *From the relative situation* of these two classes of rocks,

538 *The distinction* of their mineral characters, and mode of aggregation, and *their contents*, a conclusion is drawn that they were the results of different agencies, the former deposited from *water*, the latter produced by *heat*.

538 The division of geological study into two branches is thus indicated, and the sections of the Treatise which follow are made to correspond.

On Stratification in general.

538 *Strata:* the definition of Professor Playfair limited; *interposed* strata are described; the *thickness* and *lamination*, *parallel* or *oblique*, are noticed; and certain *collective terms* employed by Geologists explained.

539 *The series of British strata* is then presented in a tabular form, under the divisions of tertiary, secondary, and primary strata, according to the several *formations* and stratified groups.

Disturbed Stratification.

540 *Cuvier's fundamental principle* for investigation of disturbances of strata applied to cases of *vertical strata* and *contorted beds*. (See pl. i. fig. 4.)

541 *Faults*, or the lines of fracture of disturbed strata, considered with reference to a certain law of direction, (also applied to several mineral veins and dykes,) and to their relative antiquity; *principal epochs* of convulsion ascertained by this process of reasoning, and the leading physical features of the Earth's surface shown to be dependent on subterranean movements.

542 *These movements, and the disruptions of* strata which they have occasioned, are shown to be a part of the general plan of terrestrial creation, affording that variety of surface and conditions to which organic life is known to be adapted, and causing the exposure, under varied circumstances, for the use of man, of all the minerals and other useful products near the surface of the Earth. (See pl. i. fig. 5, 6, 7, 8.)

Internal Structure of Rocks.

543 *Joints in different rocks* possess peculiar characters, and communicate to them distinctive features, independent of their other structural peculiarities.
The general cause of joints and fissures admitted to be contraction of the mass after partial consolidation; some general agency, like that of electricity, appealed to for the production of the symmetry and constant direction of joints in large districts; and *local changes of internal structure* referred to the application of long-continued heat. (See pl. i. fig. 9.)

Mineral Composition of Strata.

544 *Both mechanically transported sediments* and *chemical precipitates* are recognised among the stratified rocks, *the whole series* of which consists of alternate layers of several calcareous, arenaceous, argillaceous, ferruginous, and carbonaceous compounds.

545 *The phenomenon of alternation* must be distinguished from that of *gradation* of beds, though both aid to produce what is called a transition of terms in the stratified masses. (See pl. i. fig. 10, 11.)
The proportions of chemical and mechanical deposits vary in the different systems, and give occasion to some general reflections as to the causes concerned.

Condition of Organic Remains.

546 *What tribes* of living beings are recognisable in the fossil state;
What portions of the original structure are preserved;
In what condition they were imbedded; entire, disjoined, fragmented, or worn; these questions having been answered,

547 *Subsequent changes* of composition may be investigated,
In plants, corals, shells, &c., and the effects discovered may be compared with *analogous modern* processes, and referred to the original nature of the bodies and to the peculiar influences to which they were subjected in different rocks.

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